IS 3070-3 (1993): Lightning Arresters for Alternating Current Systems, Part 3: Metal Oxide Lightning Arresters Without Gaps [ETD 30: Surge Arresters]

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Indian Standard

LIGHTNING ARRESTERS FOR ALTERNATING CURRENT SYSTEMS — SPECIFICATION

PART 3 METAL OXIDE LIGHTNING ARRESTERS WITHOUT GAPS

UDC 621·316·933

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Surge Arresters Sectional Committee, ETD 30

CONTENTS

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Surge Arresters Sectional Committee had been approved by the Electrotechnical Division Council.

(Continued on third cover)

Indian Standard

LIGHTNING ARRESTERS FOR ALTERNATING CURRENT SYSTEMS — SPECIFICATION

PART 3 METAL OXIDE LIGHTNING ARRESTERS WITHOUT GAPS

1 SCOPE

This standard applies to non-linear metal oxide resistor type surge arresters without spark gaps designed to limit voltage surges on a.c. power circuits including low voltage type.

This standard basically applies to all metal oxide surge arresters; however, polymeric housed, gas insulated, liquid immersed arresters may require special considerations in design, test and application.

This standard does not cover arresters/varistors required for telecommunication and industrial electronic applications.

1.1 Service Conditions

1.1.1 *Normal Service Conditions*

Surge arresters which conform to this standard shall be suitable for normal operation under the following normal service conditions:

a) Ambient air temperature within the range of −10°C to +50°C

b) Solar radiation

NOTE — The effects of maximum solarr adiation (1.1 kW/m²) have been taken into account by pre-heating the test specimen in the type tests. If there are other heat sources neat the arrester, the application of the arrester shall be subjected to an agreement between the manufacturer and the purchaser.

c) Altitude not exceeding 1 000 m

d) Frequency of the a.c. power supply not less than 48 Hz and not exceeding 52 Hz.

e) Power frequency voltage applied continuously between the terminals of the arrester not exceeding its continuous operating voltage.

f) Mechanical conditions:

i) Maximum wind speed : 55 m/s

ii) Seismic acceleration : 0·3 g horizontal and 0·15 g vertical.

1.1.2 *Abnormal Service Conditions*

The use of this standard in case of abnormal service conditions is subject to agreement between the manufacturer and the purchaser. A list of possible abnormal service condition is given in Annex A.

1.2 References

The following Indian Standards are necessary adjunct to this standard:

IS No.	*Title*
2071 (Part 1) : 1974	Methods of high voltage testing: Part 1 General definitions and test requirements (*first revision*)
2070 (Part 2) : 1976	Part 2 test procedure (*first revision*)
5621 : 1980	Hollow insulators for use in electrical equipment (*first revision*)
6209 : 1982	Methods for partial discharge measurement (*first revision*)

2 DEFINITIONS

2.1 Metal Oxide Surge Arrester Without Gaps

An arrester having non-line, metal oxide resistors connected in series and/or in parallel without any integrated series or parallel spark gaps.

2.2 Non-Linear Metal Oxide Resistor

The part of the surge arrester which by its non-linear voltage current characteristics acts as a low resistance to over voltages, thus limiting the voltage across the arrester terminals and as a high resistance at normal power frequency voltage.

2.3 Internal Grading System of an Arrester

Grading components, in particular grading capacitors connected in parallel to one single or to a group of non-linear metal oxide resistors to grade the voltage distribution along the metal oxide resistor stack.

2.4 Grading Ring of an Arrester

A metal part, usually circular in shape, mounted to modify electrostatically the voltage gradient or distribution.

2.5 Section of an Arrester

A complete, suitably assembled part of an arrester necessary to represent the behaviour of a complete arrester with respect to a particular test. A section of an arrester is not necessarily a unit of an arrester.

2.6 Unit of an Arrester

A completely housed part of an arrester which may be connected in series and/or parallel with other units to construct an arrester of higher voltage and/or current rating. A unit of an arrester is not necessarily a section of an arrester.

2.7 Pressure Relief Device of an Arrester

Means for relieving internal pressure in an arrester and preventing violent shattering of the housing following prolonged passage of fault current or internal flashover of the arrester.

2.8 Rated Voltage of an Arrester (Ur)

The maximum permissible r.m.s. value of power frequency voltage between its terminals at which it is designed to operate correctly under temporary over voltage conditions for a duration of 10 seconds as established in the operating duty tests (**6.6.4** and **6.6.5**). The rated voltage is used as a reference parameter for the specification of operating characteristics.

2.9 Continuous Operating Voltage of an Arrester (Uc)

The continuous operating voltage is the designated permissible r.m.s. value of power frequency voltage that may be applied continuously between the arrester terminals (**6.4**) .

2.10 Rated Frequency of an Arrester

The frequency of the power system on which the arrester is designed to be used.

2.11 Disruptive Discharge

The phenomena associated with the failure of insulation under electric stress which include a collapse of voltage and the passage of current. The term applied to electrical breakdown in solid, liquid and gaseous dielectric and combinations of these.

NOTE — A disruptive discharge in a solid dielectric produces permanent loss of electric strength. In a liquid or gaseous dielectric the loss may be only temporary.

2.12 Puncture (Breakdown)

A disruptive discharge through a solid.

2.13 Flashover

A disruptive discharge over a solid surface.

2.14 Impulse

A unidirectional wave of voltage or current which without appreciable oscillations rises rapidly to a maximum value and falls — usually less rapidly — to zero with small, if any, loops of opposite polarity.

The parameters which define a voltage or current impulse are polarity, peak value, front time and time to half value on the tail.

2.15 Steep Current Impulse

A current impulse with a virtual front time of 1 μs with limits in the adjustment of equipment such that the measured values are from 0·9 μs to 1·1 μs. The virtual time to half value on the tail shall be not longer than 20 μs.

2.16 Lightning Current Impulse

An 8/20 current impulse with limits on the adjustment of equipment such that the measured values are from 7 μs to 9 μs for the virtual front time. The time to half value on the tail is not critical and may have any tolerance.

2.17 Long Duration Current Impulse

An impulse which rises rapidly to maximum value, remains substantially constant for a specified period and then falls rapidly to zero. The parameters which define long duration impulse are polarity, peak value, virtual duration of the peak and virtual total duration.

2.18 Peak (Crest) Value of an Impulse

The maximum value of a voltage or current impulse. In case of super-imposed oscillations (*see* **6.5.2** and **6.6.4.2**) .

2.19 Front of an Impulse

The part of an impulse which occurs prior to the peak.

2.20 Tail of an Impulse

The part of an impulse which occurs after the peak.

2.21 Virtual Origin of an Impulse

The point on a graph of voltage versus time

or current versus time determined by the intersection between the time axis at zero voltage or zero current and straight line drawn through two reference points on the front of the impulse. For current impulses the reference points shall be 10 percent and 90 percent of the peak value.

NOTE — This definition applied only when scales of both ordinate and abscissa are linear. (*see* also Note in **2.22**)

2.22 Virtual Front Time of a Current Impulse (T 1)

The time in microseconds equals 1·25 multiplied by the time taken in microseconds for the current to increase from 10 percent to 90 percent of its peak value.

NOTE — If oscillations are present on the front the reference points at 10 percent and 90 percent should be taken on the mean curve drawn through the oscillations.

2.23 Virtual Steepness of the Front of an Impulse

The quotient of the peak value and the virtual front time of an impulse.

2.24 Virtual Time to Half Value of the tail of an Impulse (T 2)

The time interval between the virtual origin and the instant when the voltage or current has decreased to half its peak value. This time is expressed in microseconds.

2.25 Designation of an Impulse Shape

A combination of two numbers, the first representing the virtual front time (T 1) and the second the virtual time to half value on the tail (T 2) in microseconds. It is written as T 1/T 2 the sign "/" having no mathematical meaning.

2.26 Virtual total Duration of the Peak of a Long Duration Current Impulse

The time during which the amplitude of the impulse is greater than 90 percent of its peak value.

2.27 Virtual Total Duration of a long Duration Current Impulse

The time during which the amplitude of the impulse is greater than 10 percent of its peak value. If small oscillations are present on the front, a mean curve should be drawn in order to determine the time at which the 10 percent value is reached.

2.28 Peak Value of Opposite Polarity of an Impulse

The maximum amplitude of opposite polarity reached by a voltage or current impulse when it oscillates about zero before attaining a permanent zero value.

2.29 Discharge Current of an Arrester

The impulse current which flows through the arrester.

2.30 Nominal Discharge Current of an Arrester

The peak value of discharge current having a 8/20 impulse shape which is used to classify an arrester.

2.31 High Current Impulse of an Arrester

The peak value of discharge current having a 4/10 impulse shape which is used to test the thermal stability of the arrester on direct lightning strokes (**6.6.4.2**).

2.32 Switching Current Impulse of an Arrester

The peak value of dischrarge current having a virtual front time greater than 30 μs but less than 100 μs and a virtual time to half value on the tail of roughly twice the virtual front time.

2.33 Continuous Current of an Arrester

The continuous current is the current flowing through the arrester when energized at the continuous operating voltage.

NOTE — The continuous current, which consists of a resistive and a capacitive component, may vary with temperature and stray capacitance effects. The continuous current of test sample may, therefore, not be the same as the continuous current of a complete arrester.

The conutinuous current is for comparison purposes expressed either by its r. m. s. or peak value.

2.34 Dry Arcing Distance

Dry Arcing Distance is the shortest insulating distance or sum of such distances in the case of multiple unit arresters between the line terminal and ground terminal of the arrester.

2.35 Reference Current of an Arrester

The reference current is the peak value of the resistive component of a power frequency current used to determine the reference voltage of the arrester. The reference current shall be high enough to make effects of stray capacitances at the measured reference voltage of the arrester units (with designed grading system) negligible and shall be specified by the manufacturer.

NOTE — Depending on the nominal discharge current and/or line discharge class of the arrester, the reference current will be typically in the range of 0·05 to 1·0 mA/cm² of ~~disc area for~~ single column arresters.

2.36 Reference Voltage of an Arrester (Uref)

The lowest peak value independent of polarity of power frequency voltage, divided by $\sqrt{2}$ measured at the reference current of an arrester. The reference voltage of a multi-unit arrester is the sum of the reference voltages of the individual units.

NOTE — Measurement of reference voltage is necessary for the selection of correct test sample in the operating duty test (**6.6**).

2.37 Residual Voltage (Discharge Voltage) of an Arrester (Ures)

The peak value of voltage that appears between the terminals of an arrester during the passage of discharge current.

2.38 Power Frequency Voltage Withstand Versus Time Charactristics of an Arrester

The power frequency voltage versus time characteristics shows the maximum time durations for which corresponding power frequency voltages may be applied to arresters without damage or ensueing thermal instability under specified conditions (**6.6.7**).

2.39 Prospective Symmetrical Fault Current of a Circuit

The symmetrical current which would flow at a given location in a circuit if it were short-circuited at that location by a link of negligible impedance.

2.40 Protective Characteristics of an Arrester

The combination of the following:

a) Residual voltage for steep current impulse according to **6.4.1.**

b) Residual voltage versus discharge current characteristic for lightning impulses according to **6.4.2.**

c) Residual voltage for switching impulse according to **6.4.3.**

The lighting impulse protection level of the arrester is the maximum residual voltage for the nominal discharge current.

The switching impulse protection level of the arrester is the maximum residual voltage at the specified switching impulse currents.

2.41 Thermal Runaway of an Arrester

The term 'Thermal Runaway' is used to describe a situation when the sustained power loss of an arrester exceeds the dissipation capacity of the housing and connections, leading to a cumulative increase in the temperature of the resistor elements culminating in failure.

2.42 Thermal Stability of an Arrester

An arrester is thermally stable if after an operating duty/Pollution test causing temperature rise, the temperature or wattloss or resistive component of current of the resistor elements decreases with time when, the arrester is energized at a specified continuous operating voltage and at specified ambient conditions.

2.43 Arrester Disconnector

A device for disconnecting an arrester from the system in the event of arrester failure to prevent a persistent fault on the system and to give visible indication of the failed arrester.

NOTE — Clearing of the fault current through the arrester during disconnection generally is not a function of the device.

2.44 Type Tests

Tests carried out to prove conformity with the specification. These are intended to prove the general qualities and design of a given type of arrester.

2.45 Routine Tests

Tests carried out on each arrester or unit or section or both of the arrester and on parts to check requirements which are likely to vary during production.

2.46 Acceptance Tests

Tests carried out on samples taken from the lot for the purpose of acceptance of the lot.

2.46.1 *Lot*

All the lightning arresters of the same type and design manufactured under similar conditions of production, offered for acceptance : a lot may consist of the whole or part of the quantity ordered.

3 IDENTIFICATION AND STANDARD RATINGS

3.1 Arrester Identification

Metal oxide surge arresters shall be identified by the following minimum information which shall appear on a name plate permanently attached to the arrester:

— continuous operating voltage

— rated voltage

- rated frequency, if other than the standard frequency (3.3)
- nominal discharge current
- pressure relief rated current in kA r.m.s. (for arresters fitted with pressure relief devices) (6.7)
- the manufacturers name or trade-mark, type and identification of the complete arrester
- identification of the assembling position of the unit (for multi-unit arresters only)
- the year of the manufacture
- Serial number (only for arresters of 60 kV and above).

3.2 Standard Rated Voltages

Standard values of rates voltage for arresters (in kilovolts r.m.s. are specified in Table 1 in equal voltage steps within specified voltage ranges.

Table 1 Steps of Rated Voltages

Range of Rated Voltage, kV	Steps of Rated Voltage, kV
(1)	(2)
0·175 — 3	Under Consideration
3 — 30	1
30 — 54	3
54 — 96	6
96 — 288	12
288 — 396	18
396 — 756	24

NOTE — Other values of rated voltage may be accepted, provided they are multiples of 6.

3.3 Standard Rated Frequency

The standard rated frequency is 50 Hz.

3.4 Maximum protection levels of surge arresters as given below:

Maximum Protection Levels of Surge Arresters*

Rated Voltage	Steep Current Protection Level at 10 kA	Lightning Impulse Protection Level			Switching Protection Level at 1 kA
		1·5 kA	5 kA	10 kA	
0·175	3·0	2·2	—	—	—
0·280	3·5	2·5	—	—	—
0·500	4·5	3·0	—	—	—
0·660	6·0	5·0	—	—	—
1·000	9·0	6·0	—	—	—
3	12	—	10	10	—
4·5	18	—	15	15	—
6	24	—	20	20	—
7·5	30	—	25	25	—
9	35	—	30	30	—
10·5	40	—	35	35	—
12	45	—	40	40	—
21	80	—	75	75	—
24	95	—	85	85	—
27	105	—	95	95	—
30	110	—	105	100	—
36	130	—	—	115	—
54	200	—	—	175	—
57	210	—	—	185	—
60	220	—	—	195	—
66	240	—	—	215	—
84	310	—	—	275	—
90	330	—	—	295	—
96	355	—	—	315	—
102	380	—	—	335	—
108	400	—	—	355	—
114	420	—	—	375	—
120	440	—	—	395	—
132	485	—	—	435	—
180	665	—	—	590	—
186	685	—	—	610	—
198	730	—	—	650	—
216	795	—	—	710	—
330	900	—	—	800	660
360	975	—	—	850	720
390	1050	—	—	900	780
600	1565 (at 20 kA)	—	—	1375 (at 20 kA)	1230 (at 2 kA)
612	1595 (at 20 kA)	—	—	1400 (at 20 kA)	1255 (at 2 kA)
624	1630 (at 20 kA)	—	—	1430 (at 20 kA)	1280 (at 2 kA)
636	1660 (at 20 kA)	—	—	1455 (at 20 kA)	1305 (at 2 kA)

*Other values are under consideration.

4 ARRESTER CLASSIFICATION

4.1 Standard Nominal Discharge Currents

The standard nominal discharge currents are: 1·5 kA, 2·5 kA, 5 kA, 10 kA and 20 kA, having an 8/20 waveshape (*see* **2.16**).

4.2 Arrester Classification

Surge arresters are classified by their standard nominal discharge currents and they shall meet at least the test requirements and performance characteristics specified in Table 7.

NOTE — For 10 kA and 20 kA arresters there is an additional classification based on line discharge class (*see* **6.5.2** and Table 4).

5 GENERAL TESTING PROCEDURE

5.1 Measuring Equipment and Accuracy

The measuring equipment shall meet the relevant requirements of the latest edition of IS 2071 (Parts 1 and 2) and the values obtained shall be accepted as accurate for the purpose of compliance with the relevant clauses of this specification. All tests with power frequency voltages shall be made with an alternating voltage having a frequency between the limits of 48 Hz and 52 Hz and satisfying relevant requirements of above specification.

5.2 Test Samples

Except when specified otherwise, all tests shall be made on the same arresters, arrester section or arrester units. They shall be new, clean, completely assembled (e.g. with grading rings if applicable) and arranged as nearly as possible to simulate in-service conditions.

When tests are made on sections it is necessary that the sections represent the behaviour of all possible arresters within the manufacturer's tolerances with respect to the specific test.

The samples to be chosen for the line discharge test (**6.5**) and operating duty test (**6.6**) must have a reference voltage value at the lowest end of the variation range declared by the manufacturer. Furthermore, in case of the multicolumn arresters, the highest value of uneven current distribution must be considered. In order to comply with this demand the following must be fulfilled:

The ratio between rated voltage of the complete arrester to the rated voltage of the section is defined as **n**. The volume of the resistor elements used as test samples must not be greater than the minimum volume of all resistor element used in the complete arrester divided by **n**.

— The reference voltage of the test section should be equal to k.Ur/n where k is the ratio between the minimum reference voltage of the arrester and its rated voltage. In case Uref > k.Ur/n for an available test sample, the factor **n** has to be reduced correspondingly. (In case Uref < k.Ur/n the arrester may absorb too much energy. Such a section can be used only after agreement from the manufacturer).

— For multi-column arresters the distribution of the current between the columns shall be measured at the impulse current used for current distribution test [**7.1** (e)]. The highest current value shall not be higher than an upper limit specified by the manufacturer.

5.3 Reference Voltage Measurements

The reference voltage of an arrester (**2.26**) is measured on sections and units when required. The measurement shall be performed at an ambient temperature within 5°C to 40°C and this temperature shall be recorded. The value of the reference current used refers to the highest peak independent of polarity.

NOTE — As an acceptable approximation, the peak value of the resistive component of current can be taken to correspond to the momentary value of the current at the instant of voltage peak.

6 TYPE TESTS

6.1 General

The following type test shall be made as far as required in Table 7.

1. Insulation withstand test (**6.2**)

   These tests demonstrate the ability of the arrester housing to withstand voltage stresses under dry and wet conditions.

2. Residual voltage tests (**6.4**)

   These tests demonstrate the protective levels of the arrester.

3. Long duration current impulse withstand test (**6.5**)

   These tests demonstrate the ability of the resistor elements to withstand possible dielectric and energy stresses and to prevent puncture or flashover.

4. Operating duty tests (**6.6**)

   These tests demonstrate the thermal stability of the arrester under defined conditions.

5. Pressure relief test (**6.7**)

   For arresters fitted with pressure relief devices these tests demonstrate the ability of the arrester housing to withstand short circuit currents without violent shattering of the housing under specified tests conditions.

6. Tests of arrester disconnectors (**6.8**)

   For arresters fitted with disconnectors these tests demonstrate the correct operation of the disconnector.

7. Artificial pollution test on porcelain housed arresters (Annex I). This test is made to show that the internal parts of the arrester including its grading system—are able to withstand pollution without any damage and that the external insulation does not flashover.

   NOTE — For non-porcelain housed arresters the test procedure has to be decided by an agreement between the manufacturer and the purchaser.

8. For porcelain housed arresters : (Annex H)

   a) Temperature cycle test on hollow porcelain housings. This test is required to demonstrate the ability of porcelain housing to withstand repeated temperature cycling to simulate varying temperature conditions

   b) Porosity test

      This test is required to demonstrate that porcelain is fully vitrified.

9. Galvanizing test on exposed ferrous metal parts : (Annex H) This test is required to verify that galvanizing is adequate to withstand outdoor exposure of all ferrous metal parts.

6.2 Insulation Withstand Tests on the Arrester Housing

6.2.1 *General*

The voltage withstand tests demonstrate the voltage withstand capability of the external insulation of insulator housed arresters. For other designs the test has to be agreed upon between the manufacturer and the purchaser.

The tests shall be performed in the conditions and with the test voltages specified in **6.2.2.** The outside surface of insulating parts shall be carefully cleaned and the internal parts removed or rendered inoperative to permit these tests.

6.2.2 *Tests on Individual Unit Housing*

The applicable tests **6.2.6, 6.2.7** and **6.2.8** shall be run on the longest arrester housing. If this does not represent the highest specific voltage stress per unit length, additional tests shall be performed on the unit housing having the highest specific voltage stress. The internal parts may be replaced by an equivalent arrangement (for example, grading elements) to provide linear voltage distribution along the arrester axis.

6.2.3 *Tests on Complete Arrester Housing Assemblies*

The applicable tests **6.2.6, 6.2.7** and **6.2.8** shall be run on the complete arrester housing assembly with all external grading components fitted as in service. Internal parts may be replaced by an equivalent arrangement (for example, grading elements) to provide linear voltage distribution along the arrester axis.

6.2.4 *Ambient Air Conditions During Tests*

Regarding standard reference atmospheric conditions reference can be made to IS 2071.

The voltage to be applied during a withstand test is determined by multiplying the specified withstand voltage by the correction factor K = kd.kh, kd being air density correction factor and kh the humidity factor (rod-rod configuration).

Humidity correction factor shall not be applied for wet tests.

6.2.5 *Wet Test Procedure*

The external insulation of outdoor arrester shall be subjected to wet withstand tests under the test procedure given in IS 2071.

6.2.6 *Lightning Impulse Voltage Test*

The arrester housing shall be subjected to a standard lightning impulse voltage dry test according to IS 2071.

Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The arrester shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two for each series of 15 impulses. For test voltages refer Table 2.

If the dry arcing distance or the sum of the partial dry arcing distances in metres is larger than the test voltage ~~divided by~~ 500 kV/m, this test is not required.

6.2.7 *Switching Impulse Voltage Test*

The 10 kA and 20 kA arresters housing with highest system voltage above 245 kV shall be subjected to a standard switching impulse voltage test according to IS 2071. Arresters for outdoor use shall be tested in wet and arresters for indoor use in dry conditions.

Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The arrester shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two for each series of 15 impulses. For test voltages refer Table 2.

6.2.8 *Power Frequency Voltage Test*

Housings of arresters for outdoor use shall be tested in wet, condition and these for indoor use in dry conditions.

6.2.9 *Test Voltages*

The test voltages for all clauses are given in Table 2.

Table 2 Voltage Withstand Tests on Arrester Housing

(*Clauses* 6.2.7)

Highest System Voltage kV rms	Power Frequency Test Voltage kV rms	Lightning Impulse Test Voltage kV Peak	Switching Impulse Test Voltage kV Peak
(1)	(2)	(3)	(4)
0·440	2·5	10	—
1·0	3·5	14	—
3·6	10	40	—
7·2	20	60	—
12·0	28	75	—
24·0	50	125	—
36	70	170	—
72·5	140	325	—
123	230	550	—
145	275	650	—
245	460	1 050	—
420	—	1 425	1050
800	—	2 400	1 550

6.3 Bending Test on Arrester Housing Assemblies

6.3.1 This test for mechanical bending strength is to be done on individual units as well as on stacks with at least two assembled units on type test basis. The equivalent load to give same bending moment at the base shall be applied to the free end of the arrester unit. The direction of loading shall be at right angles to the axis of the housing and shall pass through the same axis. The bending moment shall be specified by the purchaser to cover effects of wind loads, short circuit forces and line lead pulls. On agreement with manufacturer and purchaser, the test may also be done as special acceptance test.

6.3.2 *Test for Deflection Under Load*

This test is not normally required except when rigidity and small deflections are important. When made this test is subjected to agreement between the purchaser and the manufacturer.

6.3.2.1 The complete arrester housing shall be subjected to a bending load as described in **6.3.1**. The deflection shall be measured at the point at which the load is applied and as the load is increased the deflection shall be recorded when it reaches 20 percent and 50 percent of the specified minimum failing load. By special agreement, additional measurements of deflection may also be made at other loads up to 80 percent of the specified minimum failing load.

6.4 Residual Voltage Tests

The purpose of the residual voltage type test is to verify the specified protection levels by establishing the ratio between residual voltage at specified impulse currents and the voltage level checked in routine tests. This latter voltage level can be either the reference voltage or the residual voltage at a suitable lightning impulse current in the range 0·01 to 2 times the nominal discharge current depending on the manufacturer's choice of routine test procedure.

The maximum residual voltage at a lightning impulse current used for routine tests must be specified and published in the manufacturer's type test data. The measured residual voltages of the test sections are then multiplied by the ratio of the maximum residual voltage at the routine test current to the measured residual voltage for the section at the same current to obtain maximum residual voltages for all specified currents and wave shapes.

Alternatively, for arrester with rated voltage below 1 kV — if the manufacturer chooses to check only the reference voltage by routine test — the maximum reference voltage shall be specified. The measured residual voltages of the test — sections are multiplied by the ratio of the maximum arrester reference voltage to the measured reference voltage of the test sections to obtain maximum residual voltages for all specified currents and wave shapes.

All residual voltage tests shall be made in accordance with **5.2** and **6.1** on the same three samples of complete arresters or arrester sections. The time between discharges must be sufficient to permit the samples to return to approximately ambient temperature. For multi-column arresters the test shall be performed on sections made of only one column with the current amplitudes of all applied impulses being divided by the number of columns. The corresponding measured voltages shall refer to the total current in the complete arrester.

6.4.1 *Steep Current Impulse Residual Voltage Test*

One steep current impulse (**2.15**) with peak value equal to the nominal discharge current of the arrester +5 percent shall be applied to each of the three samples, the three voltage peaks are determined and corrected as mentioned in **6.4.** The highest value is defined as the steep current residual voltage of the arrester. The response times T and T1 of the voltage measuring circuit used shall not exceed 20 μs [*see* IS 2071 (Part 2) : 1974].

6.4.2 *Lightning Impulse Residual Voltage Test*

One lightning current impulse (**2.16**) shall be applied to each of the three samples for each of the following three peak values of approximately 0·5, 1 and 2 times the nominal discharge current of the arrester. Virtual front time shall be within 7 to 9 μs while the half value time (which is not critical) may have any tolerance. The measured residual voltages are to be corrected as mentioned in **6.4.** The maximum values of the corrected residual voltage shall be drawn in a residual voltage/discharge current curve. The residual voltage read on such a curve corresponding to the nominal discharge current is to be considered for determining the lightning impulse protection level of the arrester.

NOTE — If complete arrester acceptance test cannot be carried out at one of those currents, then section tests shall be carried out at a current in the range of 0·01 to 0·25 times nominal discharge current for comparison to the complete arrester.

6.4.3 *Switching Impulse Residual Voltage Test*

One switching current impulse (**2.32**) of each specified value in Table 3 shall be applied to each of the three samples with peak values according to Table 3 (tolerance + 5 percent). The measured residual voltages are corrected as mentioned in **6.4.** The highest of the three voltage peaks is determined and defined as the switching impulse residual voltage of the arrester at the respective current. The switching impulse protection level of the arrester is defined as the highest voltage measured at the currents specified in Table 3.

Table 3 Peak Current for Switching Impulse Residual Voltage Test

(*Clause* 6.4.3)

Arrester Classification (1)	Peak Currents (A) (2)
10 kA Line discharge classes 1 & 2	125 and 500
10 kA line discharge class 3	250 and 1 000
20 kA line discharge classes 4 & 5	500 and 2 000

6.5 Long Duration Current Impulse Withstand Test

6.5.1 *General*

Before the tests the lightning impulse residual voltage at nominal discharge current of each test sample shall be measured for evaluation purposes.

Each long duration current impulse withstand test shall be made in accordance with **5.2** and **6.1** on three new samples of complete arresters, arrester sections or resistor elements which have not been subjected previously to any test except that specified above for evalution purposes. The non-linear metal oxide resistors may be exposed to the laboratory ambient air without any draft. The air temperature should be within 5 to 40°C during these tests. The rated voltage of the test samples shall be at least 3 kV if the rated voltage of the arrester is not less than this and need not exceed 6 kV. If an arrester disconnector is built into the design of the arrester under consideration, these tests must be made with the disconnector in operable condition (*see* **6.8**).

Each long duration current impulse test shall consist of 18 discharge operations divided into 6 groups of 3 operations. Intervals between operations shall be 50 s to 60 s and between groups such that the device cools to near ambient temperature.

Following the long duration current test and after the sample has cooled to near ambient temperature the residual voltage tests which were made before the long duration current test shall be repeated for comparison with the values obtained before the test and the values shall not have changed by more than 5 percent.

Visual examination of the test samples after the test shall reveal no evidence of puncture, flashover, cracking or other significant damage of the metal oxide resistors.

6.5.2 *Line Discharge Test Requirements for 10 kA and 20 kA Arresters*

This test consists in the application to the test sample of current impulse simulating the discharge through it of a precharged line as defined by the parameters given in Table 4.

Table 4 Parameters for the Line Discharge Test on 20 kA and 10 kA Arrester

(*Clause* 6.5.2)

Arrester Classification	Line Discharge Class	Surge Impedance of the Line Z (Q)	Virtual Duration of Peak T (μs)	Charging Voltage UL (kV d.c.)
(1)	(2)	(3)	(4)	(5)
10 kA	1	4·9 U_r	2 000	3·2 U_r
10 kA	2	2·4 U_r	2 000	3·2 U_r
10 kA	3	1·3 U_r	2 400	2·8 U_r
20 kA	4	0·8 U_z	2 800	2·6 U_r
20 kA	5	0·5 U_r	3 200	2·4 U_r

U_r = rated voltage of the test sample in kV r.m.s.

NOTE — The classes 1 to 5 of the preceding table correspond to increasing discharge requirements. The selection of the appropriate discharge class is based on system requirements and is dealt with in Annex B.

The energy (W) injected in the test sample is determined from parameters of Table 4 by the formula:

$$W = U_{res}{}^* \left[U_L - U_{res} \right]^* 1/Z^* \, T$$

where T is virtual duration of the peak.

U_{res} is the lowest value of the switching impulse residual voltage measured on the three test samples for the lower current value of Table 3.

The test may be carried out with any generator fulfilling the following requirements:

a) The virtual duration of the peak of the current impulse shall be between 100 percent and 120 percent of the value specified in Table 4.

b) The virtual total duration of the current impulse shall not exceed 150 percent of the virtual duration of the peak.

c) Oscillations or initial overshoot shall not exceed 10 percent of the peak of the current value. If oscillations occur, a mean curve shall be drawn for the determination of the peak value.

d) The energy for each impulse on each tested sample must lie between 90 percent and 110 percent of the above calculated value for the first impulse and between 100 percent and 110 percent of this value for the following impulses.

The current generator shall be disconnected from the test sample latter than 1·0 time and earlier than 2 times the initial total duration of the current impulses.

An example of a suitable test circuit is described in Annex E.

6.5.3 *Long Duration Current Requirements for 2.5 kA and 5 kA Arresters*

The generator used in this test shall deliver a current impulse fulfilling the following requirements:

a) The virtual duration of the peak shall lie between 100 percent and 120 percent of the value specified in Table 5.

b) The virtual total duration shall not exceed 150 percent of the virtual duration of the peak.

c) Oscillations or initial overshoot shall not exceed 10 percent of the peak current value. If oscillations occur, a mean curve shall be drawn for the determination of the peak value.

d) The peak current shall lie between 90 percent and 110 percent of the value specified in Table 5 for the first impulse and between 100 and 110 percent of this value for the following impulses.

Table 5 Requirements for the Long Duration Current Impulse Test on 2.5 kA and 5 kA Arresters

(*Clause* 6.5.3)

Arrester Classification	Peak Current (A)	Virtual Duration of Peak T (μs)
(1)	(2)	(3)
2·5 kA	50	500
5 kA	75	1 000

6.6 Operating — Duty Tests

6.6.1 *General*

These are tests in which service conditions are simulated by the application to the arrester of a stipulated number of specified impulses in combination with energization by a power supply of specified voltage and frequency. The voltage should be measured with an accuracy of ± 1 percent and measuring device should fulfil all requirements for measuring devices listed in IS 2071. Evidence to prove that power frequency current is not being limited by the source during all the twenty applications of nominal discharge current is to be provided by the manufacturer.

The main requirement to pass these tests is that the arrester is able to cool down during the power frequency voltage application, i.e., thermal runaway does not occur. It is required therefore that the arrester sections tested shall have both a transient and a steady state heat dissipation capability equal to or less than that for the complete arrester (**6.6.3**).

The test shall be made on three samples of complete arresters or arrester section in accordance with **5.1**, **5.2** and **5.3** at an ambient temperature, 5 to 40°C.

The rated voltage of the test samples shall be at least 3 kV if the rated voltage of the arrester is not lower than this and need not exceed 12 kV. If an arrester disconnector is built into the design of arrester under consideration. these tests shall be made with the disconnector in operable condition (*see* **6.8**).

For arresters rated above 12 kV it is usually necessary to make this test on an arrester section because of limitations of existing test facilities. It is important that the voltage across the test sample and the power frequency current through the sample represent as closely as possible the conditions in the complete arrester.

The critical arrester parameter for passing successfully the operating duty test is the resistor power loss. The operating duty test shall therefore, be carried out on new resistors at elevated test voltage U_c * and U_r * that give the same power losses as aged resistors at the voltage values U_c and U_r. These elevated test voltages shall be determined from the accelerated ageing procedure in the way described in **6.6.2.2**.

The power frequency test voltage to be applied to the test arrester section shall be the voltage of the complete arrester divided by the total number of similar arrester sections (i.e., Uc and Ur), corrected according to Clause **6.6.2.2** to establish the test voltages Uc* and Ur* *see* Fig. 1, 2 and 7.

NOTE — The established preheat temperature of 70 + 3°C specified in Fig. 1, 2 and 7 is a weighted average that covers the influence of ambient temperature, solar radiation and some influence of pollution on the arrester housing.

6.6.2 *Accelerated Ageing Procedure*

This test procedure is designed to determine the voltage values Uc* and Ur* used in the operating duty tests (*see* Fig. 1, 2 and 7 which will allow those tests to be carried out on new resistors).

6.6.2.1 *Test Procedure*

Three resistor samples shall be stressed at a voltage equal to the continuous operating voltage of the sample for 1 000 hours, during which the temperature shall be controlled to keep the surface temperature of the resistor at 115 ± 4°C.

During this accelerated ageing the resistor shall be in the surrounding medium used in the arrester. In this case the ageing procedure shall be carried out on single resistors in a closed chamber where the volume of the chamber is at least twice the volume of the resistor and where the density of the medium in the chamber is not less than the density oj the medium in the arrester.

NOTES

1 If the manufacturer can prove that the test carried out in open air is equivalent to that carried out in the actual medium, the ageing procedure can be carried out in open air.

2 The medium surrounding the resistor within the arrester may be subject to a modification during the normal life of the arrester. A suitable test procedure taking account of such modification is under consideration.

3 If the surrounding medium is a liquid or solid material, the ageing procedure shall be agreed upon between manufacturer and purchaser.

The relevant voltage for this procedure is the corrected maximum continuous operating voltage (U_{ct}) which the resistors must support in arrester including voltage unbalance effects. This voltage should be determined from the formula.

$$U_{ct} = U_c [1 + 0{\cdot}05 L]$$

where L is the total length of the arrester in

meters. If lower values are claimed by the manufacturer, they must be demonstrated by voltage distribution measurements or computations. Alternatively, if the voltage distribution on each unit in a multi-unit arrester is determined by measurement or by calculation, the formula is applied on the maximum stressed unit.

4 Where a procedure differing from the above formula is employed, the details of the adopted procedure for determination of voltage distribution have to be agreed upon by the manufacturer and the purchaser taking into account possible arrester mounting configuration in service.

The ageing procedure described above shall be carried out on 3 typical samples of resistor elements with a reference voltage fulfilling the requirements of **5.2**. The power frequency voltage shall fulfil the requirements stated for the operating duty test (**6.6.1**).

6.6.2.2 *Determination of elevated rated and continuous operating voltages*

The three test samples shall be heated to 115°C ± 4°C and the resistor power losses P_{1ct} shall be measured at a voltage U_{ct} 1 to 2 h after the voltage application. The resistor power losses P_{2ct} shall be measured after 1 000 h (− 0 + 100 h) of ageing under the same conditions without intermediate de-energizing of the test samples. Within the temperature range allowed both measurements shall be made at the same temperature ± 1°C.

If P_{2ct} is greater than P_{1ct} the ratio $K_{ct} = P_{2ct}/P_{1ct}$ is determined for each sample. In such case, when testing for the operating duty test, the continuous operating voltage U_c and the rated voltage U_r shall be increased to U_c^* and U_r^* respectively, in order to match the increase of power losses due to ageing. If P_{2ct} is equal or less than P_{1ct}, U_c and U_r should be used without any correction.

U_c^* and U_r^* are the highest of three values respectively, determined in the following way.

On three new resistors at ambient temperature the power losses P_{1ct} and P_{1c} shall be measured at U_c and U_r respectively; thereafter the voltages shall be increased to U_c^* and U_r^* so that the corresponding power losses P_{2c} and P_{2r} fulfil the relation:

$$\frac{P_{2c}}{P_{1c}} = K_{ct}; \quad \frac{P_{2r}}{P_{1r}} = K_{ct}$$

where K_{ct} is the biggest of the three power loss ratios determined in the ageing tests.

The measuring time should be short enough to avoid increased power loss due to heating.

6.6.3 *Heat Dissipation Behaviour of Test Sample*

6.6.3.1 *General*

In the operating duty tests the behaviour of the test sample is to a great extent dependent on the ability of the sample to dissipate heat, that is to cool down after being stressed by a discharge.

Consequently, the test sample must have a transient and a steady state dissipation capability and heat capacity equivalent to the complete arrester if correct information shall be obtained from the test. For the same ambient conditions the nonlinear metal oxide resistors in the sample and in the complete arrester should in principle reach the same temperature when subjected to the same voltage stress.

6.6.3.2 *Arrester section requirements*

This clause specifies a thermal model of the arrester section and shall be followed when thermal prorating is required:

a) The model must electrically and thermally represent a sliced portion of the active part of the arrester being modelled.

b) The housing must meet the following requirements.

   i) Meterial shall be the same as that of the arrester housing.

   ii) Inside diameter shall be the same as that of the arrester within ± 5 percent.

   iii) The total mass of the porcelain must not be more than 10 percent greater than the mass of the average porcelain section of the arrester being modelled.

   iv) The housing must be long enough to enclose the arrester section and the amount of insulation at the two ends shall be adjusted so as to meet the thermal requirements described in Annex C.

c) Maximum conductor size used for electrical connections within the sample shall be 3 mm diameter copper wire.

6.6.4 *High Current Impulse Operating Duty Test*

6.6.4.1 *General*

This test is applicable to 1·5 kA, 5 kA and 10 kA line discharge class 1 arresters and High Lightning Duty Arresters (Annex F). Typical circuit is given in Annex D.

Before the conditioning test, as the first part of the operating duty test, the lightning impulse residual voltage at nominal discharge current of each of three test samples (resistor elements) shall be determined at ambient temperature (**6.4.2**).

Thereafter the samples shall be exposed to a conditioning test consisting of twenty lightning current impulses of wave shape 8/20 (**2.16**) and having a peak value equal to the nominal discharge current of the arrester. The impulses shall be applied while the test sample is energized at 1·2 times the continuous operating voltage of the sample. The twenty impulses shall be applied in four groups of five impulses. The interval between the impulses shall be 50 to 60 seconds and the interval between groups shall be 25 to 30 minutes. It is not required that the test sample shall be energized between groups of impulses. The polarity of the current impulse shall be the same as that of the half cycle of power frequency voltage during which occurs and it shall be applied 60 ± 15 degrees before the peak of the power frequency voltage.

This conditioning test may be carried out on the resistor elements in open air at a still air temperature within 5 to 40°C. The measured peak value of the current impulse shall be within 90 percent and 110 percent of the specified peak value.

After this conditioning test the resistors are stored for future use in the operating duty tests, Fig. 1 and 7 (Annex F).

6.6.4.2 *Test procedure*

At the begining of the operating duty test the temperature of the complete section shall be within 5 to 40°C.

The arresters shall be subjected to two high current impulses with peak value and impulse shape as specified in Table 6. The high Lightning Duty Arrester specified in Annex F shall be subjected to 3 impulses with a peak value of 40 kA and 30/80 impulse shape.

Table 6

(*Clause* 6 6.4.2)

Arrester Classification (1)	Peak Current [kA] (2)
1·5 kA	10
2·5 kA	25
5 kA	65
10 kA	100
20 kA	100

NOTE — According to the conditions in normal service different values (lower or higher) may be adopted for the peak current.

Between the two impules the section shall be preheated in an oven so that the temperature at the application of the second impulse is 70 ± 3°C.

If a higher temperature is deemed necessary because of high pollution or abnormal service conditions, then the higher value is used for the test if agreed to between the manufacturer and the purchaser.

The tolerances on the adjustment of the equipment shall be such that the measured values of the current impulses are within the following limits:

a) from 90 percent to 110 percent of the specified peak value,

b) from 3·5 μs to 4·5 μs for virtual front time,

c) from 9 μs to 11 μs for virtual time to half on the tail,

d) the peak value of any opposite polarity current wave shall be less than 20 percent of the peak value of the current,

e) small oscillations on the impulse are permissible provided their amplitude in the neighbourhood of the peak of the impulse is less than 5 percent of the peak value. Under these conditions — for the purpose of measurement — a mean curve shall be accepted for determination of the peak value.

The conditioning test and the following high current impulses shall be applied at the same polarity.

As soon as possible but not later than 100 ms (in view of practical limitations in the test circuit) after the last high current impulse a

power frequency voltage equal to the corrected rated voltage (U_r*) and the corrected continuous operating voltage (U_c*) (**6.6.2**) shall be applied for a time period of 10 s and 30 min respectively to prove thermal stability or thermal runaway.

NOTE — To reproduce actual system conditions the second high current impulse is preferably applied while the sample is energised at Ur*.

The complete test sequence is illustrated in Fig. 1 for 10 kA arresters with line discharge class 1 and for 5 kA, 2·5 kA and 1·5 kA arresters and in Fig. 7 for the High Lightning Duty Arresters of Annex F. The current shall be recorded in each impulse and the current records on the same sample should show no difference that indicates puncture or flashover of the sample.

The current at the corrected continuous operating voltage (U_c*) shall be registered continuously during the power frequency voltage application.

Non-linear metal oxide resistor temperature or resistive component of current or power dissipation shall be monitored during the power frequency voltage application to prove thermal stability or thermal runaway (**6.6.6**).

Following the complete test sequence and after the test sample has cooled to near ambient temperature, the residual voltage tests which were made at the beginning of the test sequence shall be repeated.

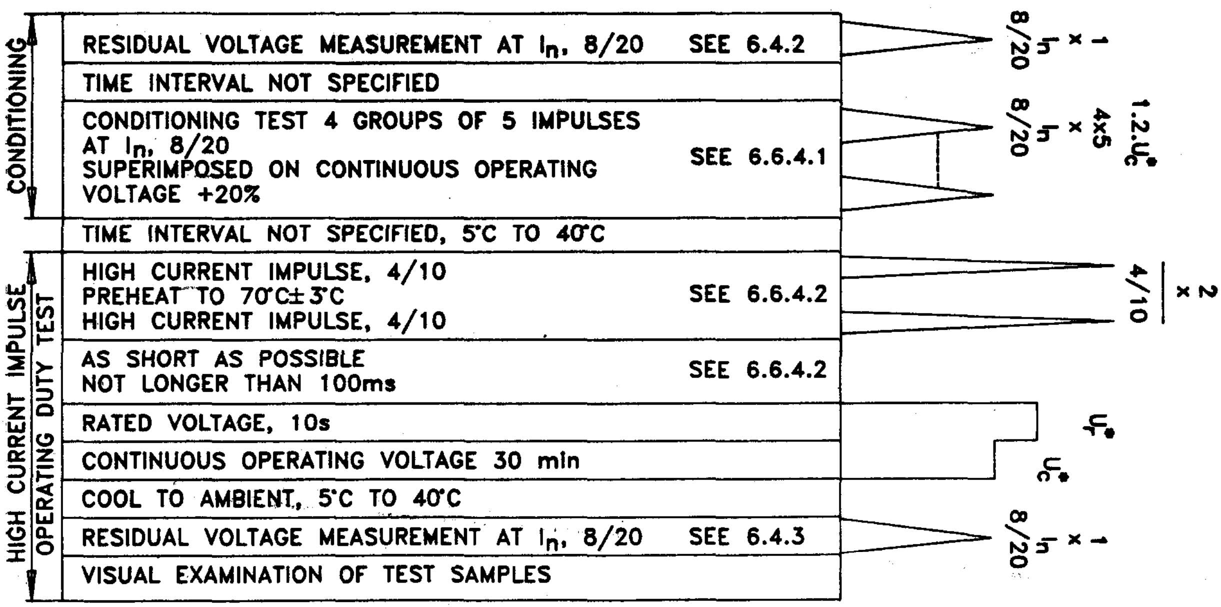
The arrester has passed the test if thermal stability is achieved, if the change in residual voltage measured before and after the test is not changed by more than 5 percent and if examination of the test samples after the test reveal no evidence of puncture, flashover or crack of the non-linear metal oxide resistors.

In addition to the above described lightning surge operating duty test the manufacturer shall supply data about the maximum allowable time duration of power frequency voltage and the corresponding voltage value which may be applied to the arrester after that the arrester has been subjected to the high current energy duty without damage or ensuing thermal runaway (*see* **6.6.7** and Annex **J**).

6.6.5 *Switching Surge Operating Duty Test*

6.6.5.1 *General*

This test applies to 10 kA line discharge classes 2 and 3 and 20 kA line discharge classes 4 and 5 arresters.



In = NOMINAL DISCHARGE CURRENT

FIG. 1 OPERATING DUTY TEST ON 10 kA LINE DISCHARGE CLASS 1·5 kA, 2·5 kA AND 5 kA ARRESTERS (*See* **6.6.4**)

Before the switching surge operating duty test the lightning impulse residual voltage at nominal discharge current of each three test samples (resistor elements) shall be determined at ambient temperature (**6.6.2**).

The test samples shall be suitably marked to ensure the correct polarity of application in the following sub-clauses.

Thereafter the samples shall be exposed to a conditioning test consisting of twenty current impulses of impulse shape (**2.16**) and a Peak value equal to the nominal discharge current of the arrester. The impulse shall be applied while the test sample is energized at 1·2 times the continuous operating voltage of the sample. The twenty impulses shall be applied in four groups of five impulses. The interval between the impulses shall be 50 to 60 s and the interval between groups shall be 25 to 30 minutes. It is not required that the test sample shall be energized between groups of impulses. The polarity of the current impulse shall be the same as that of the half cycle of power frequency voltage during which it occurs and it shall be applied 60 ±15 degrees before the peak of the power frequency voltage.

The first part of the conditioning may be carried out on the resistor elements in open air at a still air temperature of 5°C to 40°C. This is followed by two high current impulses with impulse shape and amplitude as specified in Table 4 (**6.6.4.2**). The measured peak value of the current impulses shall be within 90 percent and 110 percent of the specified peak value. After this conditioning the sections are stored for future use in the switching surge operating duty test (Fig. 2).

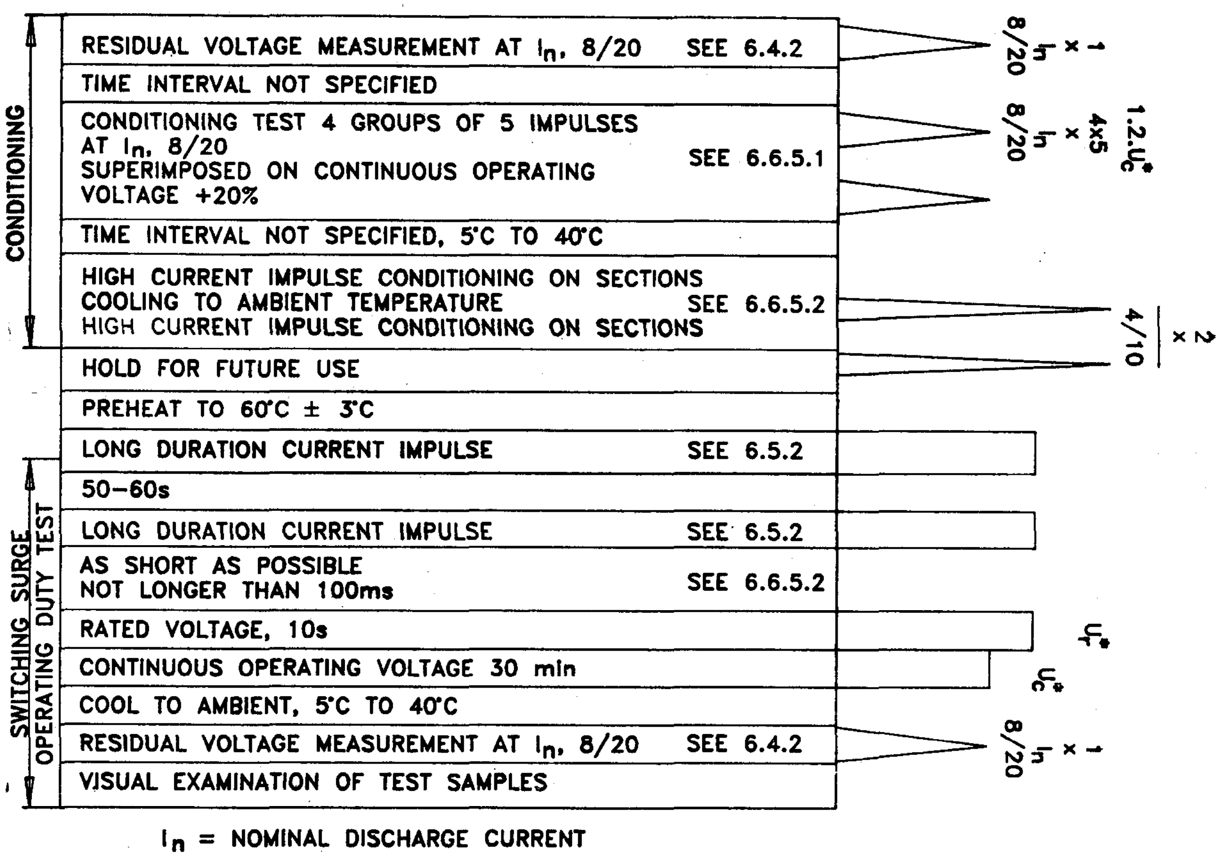


FIG. 2 OPERATING DUTY TEST ON 10 kA ARRESTERS LINE DISCHARGE CLASSES 2, 3 AND 20 kA ARRESTERS LINE DISCHARGE CLASSES 4 AND 5 (*See* **6.6.5**)

6.6.5.2 Test procedure

At the beginning of the switching surge operating duty test, that is ~~before the~~ application of two long duration current impulses, the temperature of the complete section shall be 70 ± 3°C and the ambient temperature shall be within 5 to 40°C. If a higher temperature is deemed necessary because of high pollution or abnormal service conditions, then the higher value is used for the test if agreed to between manufacturer and purchaser.

The arresters shall be subjected to two long duration current impulses as specified in **6.5.2**. Table 4 for the relevant line discharge classes. The time interval between the impulses shall be 50 to 60 s. The conditioning impulses and the long duration current impulses shall be applied with the same polarity.

After the second long duration current impulse the section shall be disconnected from the line and connected to power frequency source as soon as possible but not later than 100 ms after the impulse (in view of the practical limitations for the test circuit). The corrected rated voltage (Ur*) and the corrected continuous operating voltage (Uc*), determined from the accelerated ageing procedure described in **6.6.2**, shall be applied for a time period of 10 s and 30 min respectively to prove thermal stability or thermal runaway.

NOTE — To reproduce actual system conditions, the second long duration current impulse should be applied while the sample is energized at Ur*. In view of practical limitation in the test circuit the Time delay of 100 minutes permitted.

Oscillographic records of the voltage across and current through the test sample shall be made at the second long duration current impulse. The energy dissipated by the test sample during the second operation shall be determined from the voltage and current oscillograms and the energy value shall be reported in the type test report. The current and voltage shall be registered continuously during the power frequency voltage application.

Non-linear metal oxide resistor temperature or resistive component of current or power dissipation shall be monitored during the power frequency voltage application to prove thermal stability or thermal runaway.

Following the complete test sequence and after the test sample has cooled to near ambient temperature, the residual voltage tests which were made at the beginning of the test sequence, shall be repeated. The complete test sequence is illustrated in Fig. 2.

The arrester has passed the test if thermal stability is achieved (**6.6.6**), if the change in residual voltage measured before and after the test is not changed by more than 5 percent and if examination of the test samples after the test reveals no evidence of puncture, flashover or crack of the non-linear metal oxide resistors.

6.6.6 *Evaluation of Thermal Stability in the Operating Duty Test*

The arrester sections subjected to the operating duty tests are considered to be thermally stable and pass the test if the peak of the resistive component of the leakage current or power dissipation or resistor temperature steadily decreases at least during the last 15 min of Uc* voltage application in the procedures shown in Fig. 1, 2 and 7 for respective types of arresters.

The peak of the resistive component of leakage current is strongly influenced by the stability of the applied voltage and also by the change in ambient temperature. Because of this, the judgement whether the arrester is thermally stable or not may in some cases not be clear at the end of the U*c voltage application. If that is the case, the time of the Uc* voltage application shall be extended until the steady decrease in the current or power dissipation or temperature is clearly confirmed. If an increasing trend of current or power dissipation or temperature is not evident within 3 h of voltage application, the stability is demonstrated.

6.6.7 *Power Frequency Voltage Versus Time Characteristics of an Arrester*

In addition to the lightning and switching surge operating duty tests described in **6.6.4** and **6.6.5**, the manufacturer shall supply data about the allowable time duration of power frequency voltage and corresponding voltage value which may be applied to the arrester after the arrester has been preheated to 70 ± 3°C and subjected to the high current or line discharge class energy duty respectively, without damage or thermal runaway.

This information shall be presented as power frequency voltage versus time curves with the impulse energy consumption prior to this power frequency voltage application stated on the above-mentioned curve.

NOTES

1 Such curves are necessary for the selection of arrester rated voltage depending on local system conditions, such as lightning, switching and temporary overvoltages.

2 The curves may be established by calculations.

3 The temporary overvoltage curve should cover the time range from 0·1 s to 20 min. For arrester to be used in isolated neutral or resonant coil earthed systems without earth fault clearing, the time should be extended to 24 h.

6.6.7.1 *Procedure to verify the power frequency voltage versus time characteristics of an arrester*

If verification of the power frequency voltage versus time curve is agreed upon by the manufacturer and the purchaser, the procedure described in Annex K shall be used.

6.7 Pressure Relief Test — (Under consideration)

NOTE — In the interim period, refer Annex G.

6.8 Test of Arrester Disconnectors

6.8.1 *General*

Those tests shall be made on arresters which are fitted with arrester disconnectors or on the disconnector assembly alone if its design is such as to be unaffected by the heating of adjacent parts of the arrester in its normally installed position.

The test sample shall be mounted in accordance with the manufacturer's published recommendations using the maximum recommended size and stiffness and the shortest recommended length of connecting lead. In the absence of published recommendations, the conductor shall be hard drawn bare copper approximately 5 mm in diameter and 30 mm long, arranged to allow freedom of movement of the disconnector when it operates.

6.8.2 *Current Impulse and Operating Duty Withstand Tests*

As noted in **6.5** and **6.6** these tests will be made at the same time as the tests on the arrester in the case of built-in disconnectors. In the case of disconnectors designed for attachment to an arrester or for insertion into the line or ground lead as an accessory, these tests may be made separately or in conjuction with tests on arrester samples. The disconnector must withstand without operating each of the following tests—three new samples being used for each different test:

a) *Long Duration Current Impulse Test*

This test shall be made in accordance with **6.5** with the peak current and duration corresponding to the highest classification of arrester (*see* Tables **4** and **5**, with which disconnector is designed to be used.

b) *Operating Duty Test*

This test shall be made in accordance with **6.6** with the sample disconnector in series with a test sample section of the arrester design having the highest reference current of all the arresters with which it is designed to be used.

6.8.3 *Time/Current Curve Test*

Data for a time/current curve shall be obtained at three different symmetrically initiated current levels, viz., 20 A, 200 A and 800 A, r.m.s (± 10 percent) following through test sample disconnectors with or without arresters as required by **6.8.1**.

For tests on disconnectors affected by internal heating of the associated arresters, the non-linear resistors must be bypassed with a bare copper wire 0·08 mm to 0·13 mm in diameter in order to start the internal arcing.

For tests on disconnectors unaffected by the operation of the associated arrester, the arrester—if it is used for mounting the disconnector—shall have its non-linear resistors shunted or replaced by a conductor of size sufficient to ensure that it will not be melted, during the test.

The test voltage may be any covenient value so long as it is sufficient to maintain full current flow in the arc over the arrester elements and sufficient to cause and maintain arcing of any gaps upon which operation of the disconnector may depend. The test voltage must not exceed the rated voltage of the lowest rated arrester with which the disconnector is designed to be used.

The parameters of the test circuit should first be adjusted, with the sample shunted by a link of negligible impedance to produce the required value of current. The closing switch should be timed to close the circuit within a few electrical degrees of voltage crest so as to produce nearly symmetrical current. An opening switch may be provided with provision for adjusting time of current flow through the test sample. This switch may be omitted when accurate control over the current duration is not necessary. After the test circuit parameters, have

been adjusted, the link shunting the test sample shall be removed.

The current flow shall be maintained at the required level until operation of the disconnector occurs. At least five new samples shall be tested at each of the three current levels.

The r.m.s. value of current through the specimen and the duration of the first movement of the disconnector shall be plotted for all the samples tested. The time/current characteristic curve of the disconnector shall be drawn as a smooth curve through the points representing maximum duration.

For disconnectors which operate with an appreciable time delay, the time/current curve test shall be made by subjecting the test samples to controlled durations of current flow to determine the minimum duration for each of the three current levels which will consistently result in successful operation of the disconnector. For the point to be used for the time/current curve, successful operation of the disconnector must occur in five tests out of five trials or, if one unsuccessful test occurs, five additional tests at the same current level and duration must result in successful operations.

6.8.3.1 *Evaluation of disconnector performances*

There must be clear evidence of effective and permanent disconnection by the device. If there is no clear evidence of effective and permanent disconnection by the device, a power frequency voltage equal to 1·2 times the rated voltage of the highest rated arrester with which the disconnector is designed to be used, shall be applied for one minute without current flow in excess of 1 mA, r.m.s.

6.9 Requirements of Auxiliary Equipment — under consideration.

7 ROUTINE TESTS AND ACCEPTANCE TESTS

7.1 Routine Tests

The minimum requirement for routine tests to be made by the manufacturer shall be:

a) Measurement of reference voltage (U_{ref}) (**2.36** and **5.3**). The measured values shall be within the range specified by the manufacturer.

b) Residual voltage test. This test is mandatory for arresters with rated voltage above 1 kV. The test can be performed either on complete arresters, assembled arrester units or on single or several resistor elements. The manufacturer shall specify a suitable lightning impulse current in the range between 0·01 and 2 times nominal current at which the residual voltage is measured. If not directly measured, the residual voltage of the complete arrester is taken as the sum of the residual voltages of the resistor elements or the individual arrester units. The residual voltage for the complete arrester shall not be higher than the value specified by the manufacturer.

NOTE — When 2·5 kA and 5 kA distribution arresters below 36 kV rating are supplied in larger volumes, reference voltage measurement may be applied in routine test instead of residual voltage test under agreement between the manufacturer and the purchaser.

c) Satisfactory absence from partial discharges and contact noise shall be checked on each unit by any sensitive method adopted by the manufacturer.

d) For arrester units with sealed housing leakage check shall be made on each unit by any sensitive method adopted by the manufacturer.

e) Current distribution test for multi-column arrester. This test shall be carried out on all groups of parallel resistors. A group of parallel resistors means a part of the assembly where no intermediate electrical connection between the column is used. The manufacturer shall specify a suitable impulse current in the range 0·01 to 1 times nominal discharge current at which the current through each column shall be measured. The highest current value shall not be higher than the upper limit specified by the manufacturer. The current impulse shall have a virtual front time not less than 7 μs and the half value time may have any value.

NOTE — If the rated voltage of the groups of parallel resistors used in the design is too high compared to available test facilities, the rated voltage of the group of parallel resistors used in this test can be reduced by introducing intermediate electrical conncetions between the columns, thereby establishing several artificial groups of parallel resistors. Each such artificial group shall then pass the current distribution test specified.

Table 7 Summary of Type Test Requirements

(*Clause* 4.2, 6.1)

	Standard Norminal Discharge Current				
	20 kA	10 kA	5 kA	2·5 kA	1·5 kA
(1)	(2)	(3)	(4)	(5)	(6)
1. Rated Voltage Ur (kV rms)	390 < Ur <720	3 < Ur < 390	Ur < 138	Ur < 36	Ur < 0·66
2. Insulation withstand test on the housing arrester	Clauses 6.2.6 6.2.7	Clauses 6.2.6 6.2.7 6.2.8	Clauses 6.2.6 6.2.8	Clauses 6 2.6 6.2.8	Clauses 6.2.6 6.2.8
3. Residual Voltage Test	Table 8	Table 8	Table 8	Table 8	Table 8
a) Steep current impulse residual voltage test	Clauses 6.4.1	Clauses 6.4.1	Clauses 6.4.1	Clauses 6.4.1	Clauses 6.4.1
b) Lightning impulse residual voltage test	6.4.2	6.4.2	6.4.2	6.4.2	6.4.2
c) Switching impulse residual voltage test	6.4.3	6.4.3	Not required	Not required	Not required
4. Long duration current impulse withstand test	Clause 6.5.2	Clause 6.5.2	Clause 6.5.3	Clause 6.5.3	Not required
5. Operating duty test	Clause 6.6.4	Clause 6.6.4	Clause 6.6.4	Clause 6.6.4	Clause 6.6.4
a) High current impulse operating duty test	Table 6	Table 6	Table 6	Table 6	Table 6
b) Switching surge operating duty test	Clause 6.6.5, Table 4	Clause 6.6.5, Table 4	Not required	Not required	Not required
6. Power frequency voltager versus time curve	Clause 6.6.7	Clause 6.6.7	Clause 6.6.7	Clause 6.6.7	Clause 6.6.7
7. Pressure relief (when fitted with relief device)	Clause 6.7	Clause 6.7	Clause 6.7	Not required	Not required
8. Arrester disconnector (when fitted)	Clause 6.8	Clause 6.8	Clause 6.8	Clause 6.8	Clause 6.8
9. Artificial pollution test	←Refer Annex J→				

7.2 Acceptance Tests

7.2.1 *Standard Acceptance Test*

When the purchaser specifies acceptance tests in the purchase agreement the following tests shall be made on the nearest lower whole number to the cube root of the number of arresters to be supplied:

a) Measurement of power frequency reference voltage on the complete arrester at the reference current measured at the bottom of the arrester. The measured value shall be within the range specified by the manufacturer. For multi-unit arresters the value may deviate from the reference voltage of the arrester.

b) Lightning impulse residual voltage on the complete arrester or arrester unit (**6.4.2**) at nominal discharge current if possible or at a current value chosen according to **6.4.3.** In this case the virtual time to half value on the tail is less important and need not be complied with.

The residual voltage of a complete arrester is taken as the sum of the residual voltages of the individual arrester units. The residual voltage for the complete arrester shall not be higher than the value specified by the manufacturer.

c) For the partial discharge test the power frequency voltage applied to the complete arrester along with its end fittings, shall be increased up to its rated voltage and within 10 s decreased to 1·05 times its continuous operating voltage. At that voltage the partial discharge level according to IS 6209 shall be measured. The measured value shall not exceed 50 *p*C.

Any alteration in number of test samples or type of test shall be negotiated between the manufacturer and the purchaser.

7.3 Special Thermal Stability Test

The following test requires additional agreement between manufacturer and purchaser prior to the commencement of arrester assembly.

This test has to be performed on three totally different test sections consisting of metal oxide resistors taken from current routine production and having the same dimensions and characteristics as those of the arresters under test. The test consists of a part of the operating duty test relevant to the type of arrester as indicated in Fig. 3, 4 and 8.

Metal oxide resistor temperature or resistive component of current or power dissipation shall be monitored during the power frequency voltage application to prove thermal stability. The test is passed if thermal stability occurs in all three samples (**6.6.6**). If one sample failed, test would be carried out on three fresh test samples. No failure is permitted in this repeat test.

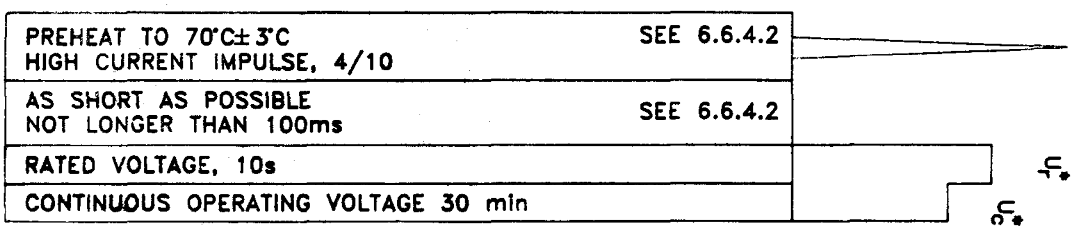


FIG. 3 THERMAL STABILITY TEST ON 10 kA LINE DISCHARGE CLASS 1·5 kA, 2·5 kA AND 5 kA ARRESTERS (*See* **7.2.2**)

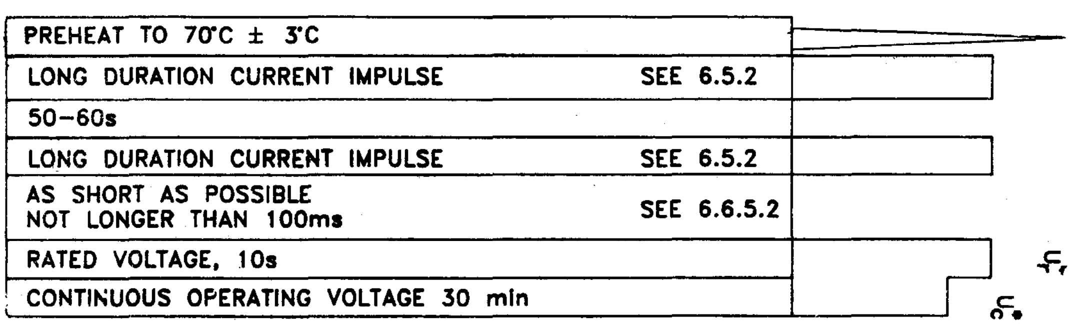


FIG. 4 THERMAL STABILITY TEST ON 10 kA ARRESTERS LINE DISCHARGE CLASSES 2, 3 AND 20 kA ARRESTERS LINE DISCHARGE CLASSES 4 AND 5 (*See* **7.2.2**)

ANNEX A

(*Clause* 1.2.2)

ABNORMAL SERVICE CONDITIONS

The following are typical abnormal service conditions which may require special consideration in the manufacture or application of surge arresters and should be called to the attention of the manufacturer.

1. Temperature in excess of 50°C or below 10°C.
2. Application at altitudes higher than 1 000 m.
3. Fumes or vapours which may cause deterioration of insulating surface or mounting hardware.
4. Excessive contamination by smoke, dirt, salt spray or other conducting materials.
5. Excessive exposure to moisture, humidity, dripping water or steam.
6. Live washing of arrester.
7. Explosive mixture of dust, gases or fumes.
8. Abnormal mechanical conditions (earthquakes and wind speed in excess of that specified in normal service conditon or vibration ice loads.
9. Unusual transportation or storage.
10. Rated frequencies below 48 Hz and above 52 Hz.
11. Heat sources near the arrester [**1.2** (b)].

ANNEX B

(*Table* 4)

GUIDE TO SELECTION OF LINE DISCHARGE CLASS

The parameters of the distributed constant impulse generator in Table 4 have been specified to obtain increasing energies with increasing discharge class for arresters having a given ratio of switching impulse residual voltage to rated voltage. The energy generated in the arrester during the test, however, is strongly dependent on the actual switching impulse residual voltage of the tested resistors. This energy can be determined with sufficient accuracy from the following formula:

$$W = \frac{U_{res}}{U_r}\left(\frac{U_L}{U_r} - \frac{U_{res}}{U_r}\right) \times \frac{U_r}{Z} \times T$$

U_r = rated voltage (rms value)

U_L = charging voltage of the generator

W = specific energy equal to the energy divided by the rated voltage

U_{res} = residual voltage at switching impulse current (**6.4.3**)

Z = surge impedance of the generator

T = virtual duration of the current peak.

The dependence of the specific energy on the switching impulse residual voltage is shown in Fig. 5.

The selection of the line discharge class is done in the following sequence:

1. Determine the energy which is generated in the metal oxide arrester in service, taking into account possible lightning and switching events.
2. Determine the specific energy by dividing the energy by the r.m.s. value of the rated voltage.
3. Compare this specific energy with the specific energy generated in the test using formula given above or Fig. 5 and select the next higher line discharge class.

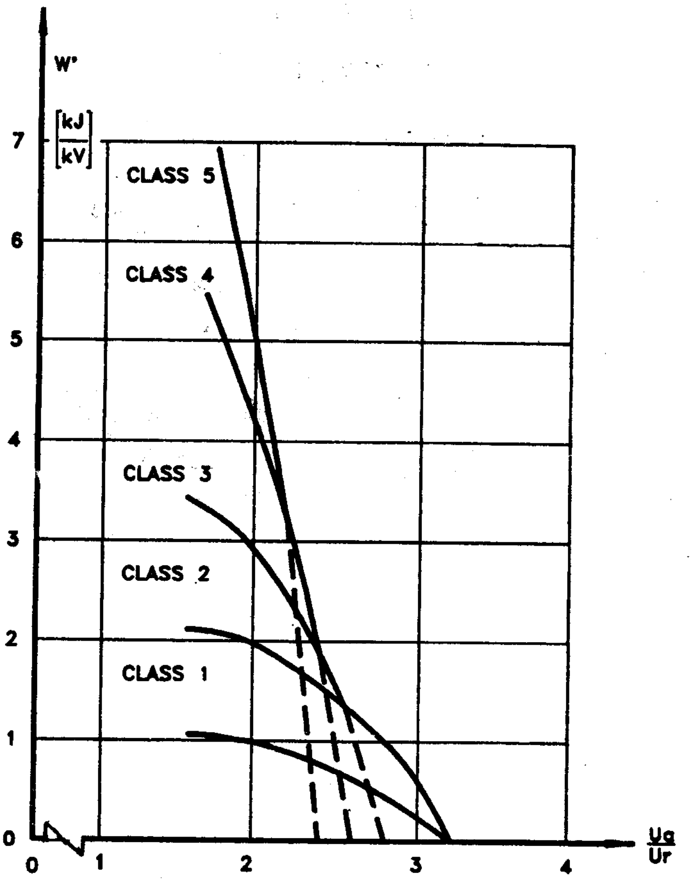


FIG. 5 SPECIFIC ENERGY IN kJ PER kV RATING DEPENDENT ON THE RATIO OF SWITCHING IMPULSE RESIDUAL VOLTAGE (U_a) TO THE r.m.s. VALUE OF THE RATED VOLTAGE U_r OF THE ARRESTER

ANNEX C

(*Clause* 6.6.3.2)

TEST TO VERIFY THERMAL EQUIVALENCY BETWEEN COMPLETE ARRESTER AND ARRESTER SECTION

A test according to the following or another procedure agreed on between the purchaser and the manufacturer shall be carried out.

The complete arrester or the unit containing most blocks per unit length of a multi-unit arrester is placed in still air ambient temperature of 5 to 40°C. The ambient temperature must be held at ±3°C. Within arrester thermocouples and/or some sensors, for example utilizing optical fibre technique to measure temperature are attached to the blocks. Sufficient number of points may be checked to calculate a mean temperature or the manufacturer can choose to measure the temperature at only one point located between 1/2 to 1/3 of the arrester length from the top. The latter will give a conservative result thus justifying the simplified method.

The resistor elements are then heated up by the application of power frequency voltage with an amplitude above reference voltage to a temperature of approximately 120°C. This temperature should correspond to a mean value if the temperature is measured on several blocks or a single value if only the 1/2 to 1/3 point is checked. The heating up time is not critical if approximately the same time is used when later heating the test section and the time could be chosen from minutes to hours depending on the power capacity of the voltage source when this predetermined temperature is reached, the voltage source shall be disconnected and the cooling time curve is determined during a period of not less than 2 hours. In the case of several measuring points a mean temperature curve is constructed.

The test section is therefore tested in the same way as the complete arrester in still air ambient temperature in the range of 5°C to 40°C. but for a given comparison ambient must be held at ± 3°C. It is heated up to the same temperature rise above ambient temperature as the complete arrester by the application of power frequency voltage. The voltage amplitude is chosen to give a heating up time approximately as long as for the complete arrester. A mean temperature is determined by measuring the temperature of several blocks or as an alternative ten temperatures only on one block located between 1/2 to 1/3 of the section from the top. When the section has reached the predetermined temperature the voltage source is disconnected and the temperature measured during cooling for a period of 2 hours.

Finally the cooling curves for the complete arrester and the section are compared. Either the mean or single values are used and recalculated to temperature above ambient temperature if ambient temperatures during test on complete arrester and section differs.

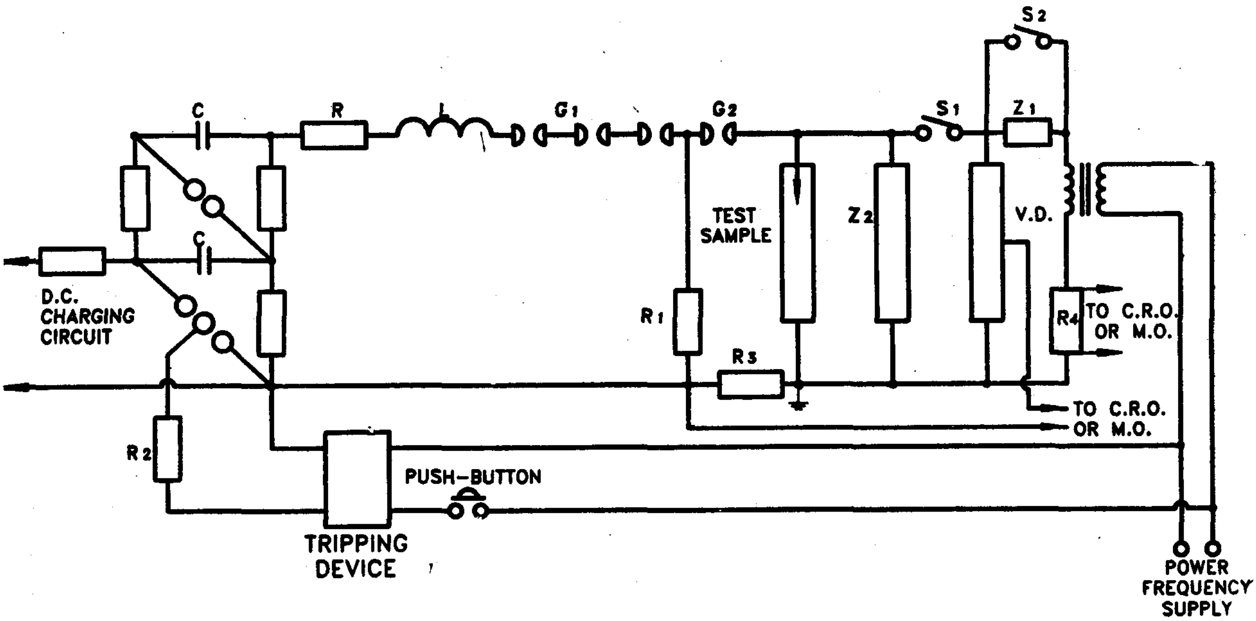
To prove thermal equivalency the test section must for all instants during the cooling period have a higher or equal temperature than the complete arrester.

ANNEX D

(*Clause* 6.6.4)

TYPICAL CIRCUIT FOR HIGH CURRENT IMPULSE OPERATING DUTY TEST

It is the purpose of this Annex to suggest a suitable test circuit (as per Fig. 6 given below) for use in the high current impulse operating duty test (*see* **6.6.4**) and to describe the function of the various circuit components rather than to specify a standard test circuit which shall be used in all tests wherever made. The requirements for the operating duty test such as the power-frequency voltage and the characteristic of the current impulse are described earlier. The exact method by which these requirements are met is not important. There are many possible variations both in the agreement of the circuit and in the choice of values for the various components.



C. R. O. = Cathode Ray Oscillograph
V. D. = Voltage Divider
M. O. = Magnetic Oscillograph
S. = Switch

FIG. 6 TYPICAL TEST CIRCUIT DIAGRAM FOR HIGH CURRENT IMPULSE OPERATING DUTY TEST

The test sample is connected via a switch S_1 to the power frequency supply, usually a transformer, although this is not essential. An impulse generator, shown as a two-stage circuit although it may be a single-stage circuit if adequate, is connected to the arrester through a resistor R, an inductor L and spark gaps G_1 and G_2. The waveshape of the current impulse is controlled by selecting suitable values for C, R and L. A low resistance non-inductive shunt R_3 and a voltage divider *V.D.* are shown for the measuments of impulse current and voltage respectively. A shunt R_4 is shown in the leads from the power transformer for recording the power frequency current through the arrester.

The spark gap which isolates the impulse generator from the arrester may be of various forms. In the type of gap shown, the resistor R_1, if used may be, of the order of a megohm and serves to maintain a point in the multiple spark gap at earth potential when no current is flowing. The part G_1 of the gap does not, therefore, have any of the power frequency voltage across it. The part G_2 of the gap is made as small as is consistent with its ability to withstand the power frequency voltage. Z_1 and Z_2 are impedences that by the switch S_2 could be used to control the power frequency voltages (U_r* and U_c* respectively) across the test sample, still fulfilling the power frequency source requirements specified earlier.

The current from the frequency source may be recorded either by a magnetic oscillograph or a cathode ray oscillograph if proper precautions are taken. The power frequency voltage may be recorded by a magnetic oscillograph or a cathode oscillograph through a voltage divider or a potential transformer. The impulse generator may be tripped as shown in the figure through a tripping device. This applies a high voltage pulse to the centre electrode of the three electrode gap in the impulse generator. A high resistance R_2 prevents appreciable impulse current flowing in the tripping circuit. The tripping of the impulse generator may be initiated by means of a push button.

ANNEX E

(*Clause* 6.5)

TYPICAL CIRCUIT FOR A DISTRIBUTED-CONSTANT IMPULSE GENERATOR FOR THE LONG DURATION CURRENT IMPULSE WITHSTAND TEST

It is the purpose of this Annex to give the principle of a suitable test circuit for use in the long duration current impulse withstand test and to describe the function of the various circuit components rather than to specify a standard test circuit which shall be used in all tests.

The requirements of waveshape, duration, charging voltage, load resistor, interval between impulses, etc are given in the test specification.

The exact method by which these requirements are met is immaterial, there are many possible variations both in the circuit and in the choice of values for the various components. Fig. 7 shows a simplified diagram of a distributed constant impulse generator. The surge impedance of the generator is determined by:

$$Z = \sqrt{\frac{L}{C}},$$ when neglecting the resistances

The number of *LC* sections of the generator will normally be about ten to produce an acceptable weveshape. To limit the oscillations at the beginning and the end of the peak of the wave, it may be necessary to increase the inductances at both ends of the generator as well as to introduce parallel resistors *R* to compensate for the reduced front steepness caused by the increased inductances.

The triggering gap can be a simple switch, if an auxiliary impulse generator is used to initiate the discharge of the distributed constant generator, the stored energy of the former shall not exceed 0·5 percent of the stored energy of the latter.

The current through and the voltage accross the arrestor sample must be recorded.

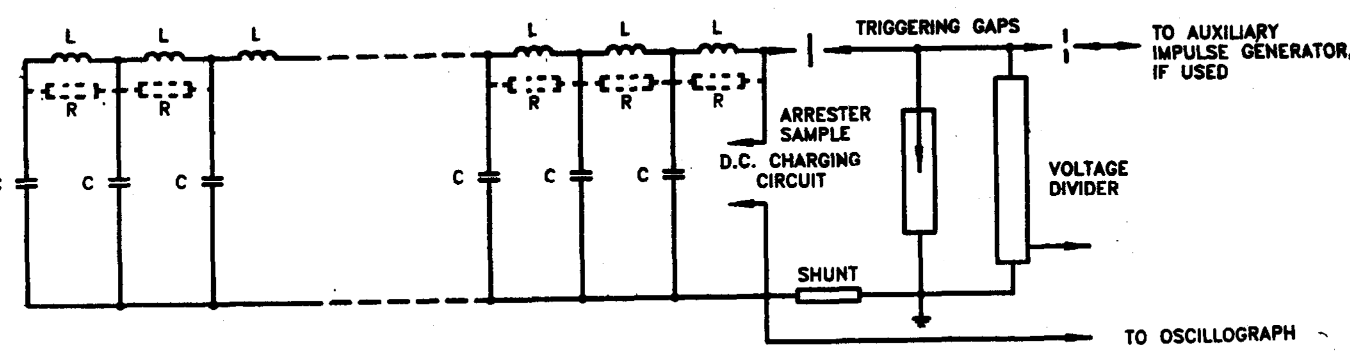


FIG. 7 TYPICAL DISTRIBUTED-CONSTANT IMPULSE GENERATOR FOR THE LONG DURATION IMPULSE TEST

ANNEX F

(*Clause* 6.6.4.1)

REQUIREMENTS ON HIGH LIGHTNING DUTY ARRESTER FOR VOLTAGE RANGE 1 kV TO 52 kV

This Annex describes the requirements on 20 kA arresters especially applicable for high lightning intensity area with highest system voltage in the range 1 kV to 52 kV.

The operating duty test shall be carried out according to **6.6.4** and shall consist of the application to each sample of three 30/80 current impulses with a peak value of 40 kA.

The time intervals between the three current impulses shall be 50 to 60 s.

The tolerances on the adjustment of the equipment shall be such that the measured values of the current impulses are within the following limits:

a) from 90 percent to 110 percent of the specified peak value.

b) from 25 μs to 35 μs for virtual front time,

c) from 70 μs to 90 μs for virtual time to half value on the tail.

d) the peak value of any opposite polarity current wave shall be less than 20 percent of the peak value of the current.

e) small oscillations on the impulse are permissible provided their amplitude in the neighbourhood of the peak of the impulse is less than 5 percent of the peak value. Under these conditions — for the purpose of measurement — a mean curve shall be accepted for determination of the peak value.

The complete test sequence is illustrated in Fig. 8.

NOTE — To reproduce actual system conditions the last high current impulse is preferably applied while the same is energized at Ur*. In view of practical limitation in the test circuit, a delay of 100 ms is permitted.

Further test requirements are specified in Table 8 and Fig. 9.

Table 8 Test Requirements on 20 kA High Lightning Duty Arresters

(*Clause* 6.6.4.1)

Test	Clause Reference
(1)	(2)
1. Rated voltage Ur (kVms) 3 $\leqslant$ Ur $\leqslant$ 60	—
2. Insulation withstand tests on the arrester housing	6.2.6, 6.2.8
3. Residual voltage test	
a) Steep current impulse residual voltage test	6.4.1
b) Lightning impulse residual voltage test	6.4.2
c) Switching impulse residual voltage test	Not required
4. Long duration current impulse withstand test	6.5.2
5. Operating duty test	
a) High current impulse operating duty test	6.6.4
b) Switching surge operating duty test	Not required
6. Power frequency voltage versus time curve	6.6.7
7. Pressure relief test (when fitted with relief device)	6.7
8. Arresters disconnector (when fitted)	6.8
9. Artificial pollution test	Annex J

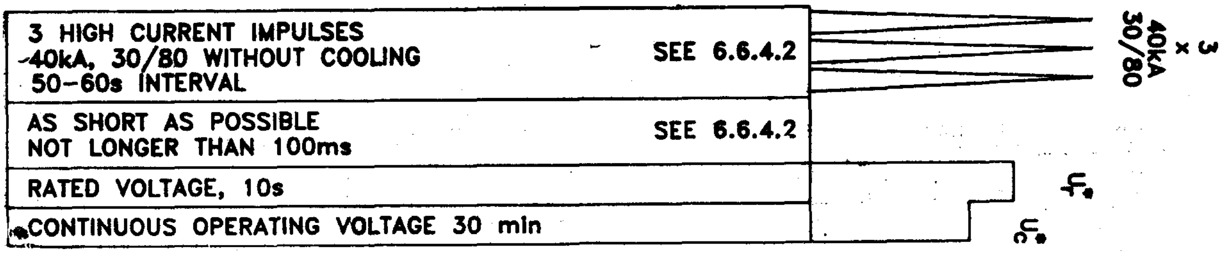


FIG. 9 THERMAL STABILITY TEST ON 20 kA HIGH LIGHTNING DUTY ARRESTER (*See* **6.6.2**)

ANNEX G

(*Clause* 6.7)

PRESSURE RELIEF TESTS

G-1 GENERAL

G-1.1 When an arrester is fitted with a pressure relief device it shall be tested in accordance with this annex. The test is made to show that an arrester failure will not cause explosive shattering of the housing. It shall demonstrate compliance with one of the pressure-relief classes given in Table 9 for all ratings of the same design.

The test sample arrester shall be the longest arrester of each different design as defined in **6.7**. Each test shall be made on a test sample contained in a new housing and fitted with all the hardware as in service.

The test sample shall be mounted to simulate installation conditions that are in accordance with the details provided by the the manufacturer. The upper end shall be terminated with the end configuration of another unit or the top terminal, whichever is the more restrictive to pressure relief. The base shall be level with the top of an approximately circular enclosure which is at least 300 mm high and which shall encircle the test sample and be concentric therewith. The diameter of the enclosure shall equal the sample diameter plus twice the sample height with minimum diameter of 1·8 m.

G-1.2 The following general requirements apply to all the several methods of making the high-current pressure-relief tests:

a) The frequency of the test supply shall be not less than 48 Hz and not more than 62 Hz.

b) For 5 kA arrester and 10 kA arresters 3 kV through 72 kV the minimum test current duration shall be 0·2 s.

c) For 10 kA arresters above 72 kV, the minimum test current duration shall be 0·1 s.

The maximum time for the arrester to vent shall be 0·085 s.

G-2 HIGH-CURRENT PRESSURE-RELIEF TESTS

The impedance of the test circuit shall be adjusted to produce not less than the symmetrical rms fault current of one of the pressure relief classes given in Table 9. The test current shall be allowed to flow for at least the required duration during tests on the sample, although shorter times may be adequate for tests to measure the prospective current and to adjust the circuit.

Tests shall be made on a single-phase circuit and at a voltage of 77 percent to 107 percent of the rated voltage of the arrester, whenever possible (**G-2.1**). However, it is expected that tests on high voltage arresters will be made at a testing station which will not have sufficient power to make the tests on all arresters at 77 percent of the rated voltage. Accordingly, two alternative procedures for making the high current pressure relief tests are given in **G-2.2** and **G-2.3**.

NOTES

1 The 77 percent voltage corresponds to the voltage applied to an arrester whose voltage rating is 75 percent of the system phase-to-phase voltage that is, at a location having an earth fault factor of 1·3. For locations having 1·39 or 1·73 earth fault factors, the phase-to-earth voltage would be 72 percent or 58 percent of the arrester voltage rating respectively.

2 When testing at reduced voltage, test circuit adjusted to comply with **G-2.2** or **G-2.3** will often produce a higher symmetrical current through the arrester, than would be obtained during tests at full voltage.

G-2.1 High Current Test at 77 Percent Rated Voltage

The prospective current shall first be measured by making a test with the arrester shunted by a solid link of negligible impedance. The circuit parameters and timing of the closing switch shall be such that the r.m.s. value of the ac component of the current shall equal or exceed the appropriate value for the pressure-relief class given in Table 9 and the peak value of the current in the first major loop shall be at least 2 6 times the minimum prospective symmetrical fault current.

G-2.2 High Current Tests at less than 77 Percent Rated Voltage

When tests are made with a test circuit voltage less than 77 percent of the voltage rating of the test sample, the test current of the arrester shall equal or exceed the appropriate value for the pressure-relief class given in Table 9 and the peak value of the current in the first major loop shall be at least 2·6 times the rms values of the claimed symmetrical current.

G-2.3 Compensated High Current Tests at less than 77 Percent Rated Voltage

The general procedure in the compensated reduced voltage test is to make a test in accordance with **G-2.1** on a rating that can be tested at full voltage to determine the current which will flow through the arrester. The test on the higher voltage rating is then made, adjusting the test circuit so as to obtain the same first major loop asymmetrical current, and not less than the same symmetrical current, that was obtained through the low-voltage unit. The arrester tested at full voltage shall be of the same type and design as the higher voltage arrester, or an adequate prorated section.

G-3 TEST EVALUATION

The test sample shall be deemed to have passed the test if the housing of the sample remains intact or if it breaks sufficiently non-explosively that all parts are contained within the circular enclosure.

Table 9 Requirement for Pressure-Relief Tests

(*Clause* G-2)

Pressure-Relief Class	Arrester Classification*		Minimum Prospective Symmetrical Fault Current kA rms
	Nominal Discharge Current, kA	Line Discharge Class	
(1)	(2)	(3)	(4)
80	20,10	5,4	80
63	20,10	5,4	63
50	10	4,3	50
40	10	3,2	40
20	10	2,1	20
10	10	2,1	10
16	5, 2.5	1000,500 μs Pt	16
5	5, 2.5	1000,500 μs Pt	5

*The association of a specific pressure-relief class with a specific arrester classification is under examination. Those tabulated above are to be taken as only indicative.

Pt — Virtual duration of peak as defined in Table 5.

ANNEX H

(*Clause* 6.1)

TEMPERATURE CYCLE TEST

H-1 The hollow insulator initially at ambient temperature shall be quickly immersed, without being placed in an intermediate container, in a water-bath maintained at a temperature t°C above that of the cold water and shall remain submerged for a period of (15+0·7 m) minutes with a maximum of 30 minutes (*m* being the mass of the hollow insulator in kilograms). It shall then be withdrawn and quickly immersed in the bath of cold water where it shall remain submerged for the same number of minutes.

H-2 This heating and cooling cycle shall be performed three times in succession. The time taken to transfer from one bath to another shall be as short as possible and shall not exeeed 30 s.

H-3 The temperature difference *t* is given in Table 10 as a function of the dimensions of the hollow insulator. This temperature difference may be marked on the drawing.

H-4 ALTERNATIVE TEST FOR LARGE HOLLOW INSULATORS

H-4.1 For hollow insulators having a height greater than 1 200 mm, the following method of test may, by agreement between the manufacturer and the purchaser, be used instead of the method of test described above.

H-4.2 The temperature of the hollow insulator shall be raised slowly by any convenient means (circulation of heated air or water, infra red radiation, etc) in a value t°C higher than that of the cold water which is later used to spray it with artificial rain. This temperature shall be maintained for 15 minutes.

H-4.3 The hollow insulator shall then be immediately sprayed with artificial rain at an intensity of about 3 mm per minute and this spraying shall continue for 15 minutes.

H-4.4 This heating and cooling cycle shall be performed three times in succession. The temperature difference *t* is given in Table 11 given below as a function of the wall thickness as defined above.

Table 11 Temperature Difference for Temperature Cycle Test on Large Hollow Insulators

(*Clause* H-4.4)

Thickness (t)	Temperature Difference °C
(1)	(2)
< 30	70
> 30	59

H-5 The volume of water contained in the baths for tests above shall be sufficiently great for the immersion of the insulator not to cause a variation of more than ± 5°C in the temperature of the water.

H-6 After the three cycle, the hollow insulator shall show no cracks or damage to the glaze or other faults causing a deterioration in its electrical or mechanical properties.

H-7 The absence of such deterioration is considered verified if the hollow insulator passes the electrical routine tests described in IS 5621 : 1980.

Table 10 Temperature Difference for Temperature Cycle Test

(*Clause* H-3)

Thickness (t) D^2 mm$^3 \times 10^3$	Temperature Difference t°C for Thickness, mm					
	⩽23	23< ϕ ⩽26	26< ϕ < 32	32< ϕ ⩽36	36< ϕ ⩽43	43< ϕ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$D^2L \leqslant 104$	60	55	50	45	40	35
$104 < D^2L \leqslant 410$	55	55	50	45	40	35
$410 < D^2L \leqslant 655$	50	50	50	45	40	35
$655 < D^2L \leqslant 900$	45	45	45	45	40	35
$900 < D^2L \leqslant 1150$	40	40	40	40	40	35
$1150 < D^2L \leqslant 2000$	35	35	35	35	35	35

D^2L. > 2000 Subject to agreement between the manufacturer and the purchaser.

D = the greatest external diameter over the sheds of the hollow insulator, expressed in millimetres

L = the height of the hollow insulator, expressed in millimetres

ϕt = the greatest thickness of material defined as the diameter, expressed in millimetres, of the largest circle which can be inscribed in the outline of a section through the axis of the hollow insulator (*see* Fig. 1).

NOTE — The temperature differences in Table 10 apply to insulators of parallel or tapered internal shape which allow free access of water to the interior on immersion. Insulators are considered not to offer free access of water if the smallest internal diameter is less than 0·25 times the largest internal diameter. In such cases, the value of *t* shall be agreed between the manufacturer and the purchaser.

H-8 POROSITY TEST ON PORCELAIN COMPONENTS

H-8.1 Pieces freshly broken from a suitable piece of porcelain fired as a control sample adjacent to the component or one of the components themselves, whichever the manufacturer prefers, shall be immersed in one percent alcoholic solution of fuchsin (1 g fuchsin in 100 g of methylated spirit) under a pressure of not less than 150 kg/cm² for a period such that the product of test duration in hours and the test pressure in kg/cm² is not less than 1 800.

H-8.2 The fragments shall then be removed from the solution, washed, dried and broken. Examination with naked eye of freshly broken surfaces shall not reveal any dye penetration. Penetration into small cracks formed during the initial breaking shall be neglected.

H-9 GALVANISING TEST ON METAL PARTS

H-9.1 The weight and uniformity of coating shall be determined by the tests given in IS 2633 and shall satisfy the requirements given in Table 12.

NOTE — In view of the scarcity of zinc which is used for galvanizing other types of anti-corrosion protection, such as aluminising may be used subject to agreement between the purchaser and the supplier. It is not possible to give definite specifications for such alternatives at present but these are expected to be included later.

Table 12 Weight of Coating

(*Clause* H-9.1)

Articles (1)	Average Coating Weight, *Min* (2) g/m²
Fabricated steel articles:	
5 mm thick and over	610
Under 5 mm, but not less than 2 mm in thickness	460
Under 2 mm, but not less than 1·2 mm in thickness	340
Castings:	
Grey iron, malleable iron	610
Threaded work other than tubes and the tube fittings:	
10 mm diameter and over	300
Under 10 mm diameter	270

ANNEX J

(*Table* 8)

ARTIFICIAL POLLUTION TESTING OF METAL OXIDE SURGE ARRESTERS WITH PORCELAIN HOUSING

J-1 ARTIFICIAL POLLUTION TEST

J-1.1 This test demonstrates the ability of the arrester to withstand the electrical stresses caused by contamination on the arrester housing. Characteristics to be examined are thermal stability and insulation withstand. The test shall be made on complete arresters. Only the highest voltage rating of each type and design shall be tested. Conformance of the highest voltage rated arrester to this standard shall be considered to demonstrate conformance of lower voltage ratings of the same arrester type and design.

J-2 POWER FREQUENCY TEST VOLTAGE SOURCE

J-2.1 The power frequency test voltage source and the method of measurement, shall be in accordance with IS 2071. The regulation of the source shall be such as to maintain the specified voltage on the arrester, except for infrequent, non-consecutive, half-cycle voltage dips of no more than 5 percent during leakage current pulses.

J-3 TEST SPECIMEN PREPARATION AND MOUNTING

J-3.1 Test specimen preparation and mounting-thermal stability of an arrester shall be demonstrated through measurement of one or more of the following:

arrester temperature; resistive component of leakage current; or wattloss.

If stability is to be demonstrated by temperature measurement, then a temperature sensing device (such as a thermocouple) shall be installed in each arrester section immediately adjacent to a valve element.

The arrester to be tested shall be assembled completely as it is intended to be used in service except as noted above.

J-4 CONTAMINANT PREPARATION

J-4.1 The contaminant shall be stored in a container so that it can be thoroughly agitated just prior to application.

The contaminant shall consist of a slurry of:

a) Water

b) Bentonite, 5 g/l of water

c) An undiluted non-ionic detergent consisting of nonyl-phenyl-polyethlene-glycol-ether or other comparable long chain non-ionic esters, 1 g/l water.

d) Sodium Chloride

The volume resistivity of the slurry shall range between 4 to 5 m and can be adjusted by the addition of sodium chloride. Volume resistivity shall be measured at a temperature of 5 to 40°C with a low-voltage conductivity bridge.

J-5 TEST PROCEDURE

J-5.1 The test shall be conducted according to the following steps:

a) The arrester housing shall be clean and dry at the ambient temperature. Washing with a detergent may be necessary to remove oil films, but the detergent should be thoroughly rinsed off with water.

b) The arrester shall be energized for a minimum of one hour at continuous operating voltage U_c. Measurements of resistive component of current, or watts loss, or temperature shall be made at the end of this period.

c) With the arrester de-energized, the contaminant shall be applied to all porcelain surfaces of the lower-half of the arrester, including the undersides of all skirts. The coating shall be applied heavily enough to form drops of the slurry on the skirts of the housing. (Too much contaminant cannot be applied; the excess merely runs off).

NOTE — The contaminant coating may be applied by dipping, spraying, or flow-coating. Small arresters may conveniently be coated with a paint spray gun. Large arresters may require special racks for mounting the spray or flow-coat nozzles.

d) Within 3 minutes of contaminant application, the arrester shall be energized at its continuous operating voltage U_c.

Measurement of resistive leakage current, watts loss, or temperature shall be made at the end of the 15 minute energization. Arrester temperature if measured, shall be obtained immediately following de-energization.

NOTE — Maximum voltage-off time for contaminent application, including any temperature measurement is 18 minutes.

e) Repeat steps (c) and (d) and at the end of the second cycle, and energize the arrester at its continuous operating voltage U_c.

J-6 TEST EVALUATION

J-6.1 The arrester shall have passed this test if:

a) the arrester demonstrates thermal stability, and

b) no unit or arrester flashes over, and

e) no physical damage of the internal parts as evidenced by inspection.

The arresters to be tested shall be assembled completely as it is intended to be used in service except as noted above.

ANNEX K

(*Clause* 6.6.7)

PROCEDURE TO VERIFY THE POWER FREQUENCY VOLTAGE VERSUS TIME CHARACTERISTICS OF AN ARRESTER

When the experimental verification of power frequency voltage versus time curve supplied by the manufacturer is agreed upon by the manufacturer and the purchaser, the last part of the duty test specified in Fig. 1, 2 and 7 in the main text depending on the category of the arrester, shall be used.

For the arresters categorized as 10 kA line discharge class 1 and 1·5 kA, 2·5 kA and

5 kA the procedure starts with preheating of the test sample to 70 ± 3°C in Fig. 1. It is followed by one high current impulse which gives the energy prior to the power frequency voltage application. The power frequency voltage versus time curve shall be verified by changing the level of the applied power frequency voltage prior to the U_c* voltage application. Three points on the curve shall be considered sufficient for verification.

The curve for the high lightning arresters in Annex F shall be verified by the last part of the operating duty test in Fig. 7. The procedure starts with the three successive applications of high current impulse on the sample at ambient temperature. The voltage versus time curve is verified by applying power frequency voltage prior to the U_c* voltage application in the same manner as for the arresters in the first category described above.

The curves for 10 kA arresters in line discharge classes 2 and 3 and 20 kA arresters in classes 4 and 5 are verified in a similar manner by the procedure in Fig. 2. First the sample is preheated to 70 ± 3° C and two shots of long duration current impulses are applied to give the energy prior to the power frequency voltage application. The voltage versus time curve shall be verified at not more than three points on the curve by applying power frequency voltage followed by the U_c* voltage application.

The residual voltage measurement at the very last in the operating duty tests in Fig. 1, 2 and 7 is omitted in all of the verification procedures.

ANNEX L

(*Foreword*)

TYPICAL INFORMATION GIVEN WITH ENQUIRIES, TENDERS AND ORDERS

L-1 INFORMATION GIVEN WITH ENQUIRY

L-1.1 System Data

— Highest system voltage

— Frequency

— Maximum voltage to earth under system fault conditions (Earth fault factor or system of neutral earthing)

— Maximum value of temporary over-voltages and their maximum durations (Earth fault, loss of load, ferroresonance)

— Insulation level of equipment to be protected

— Maximum symmetrical short circuit current of the system at the arrester location.

L-1.2 Service Conditions

Normal conditions : *see* **1.2**

Abnormal conditions:

a) Ambient conditions :

— Natural polution level (*see* IS 3716)

b) System

— possibility of generator overspeeding (voltage versus time characteristics)

— nominal power frequency other than 48 to 52 Hz

— load rejection and simultaneous earth faults

— formation during faults of a part of the system with an insulated neutral in a normally effectively earthed-neutral system

— faulty compensation of the earth-fault current bending load requirement

L-1.3 Arrester Duty

a) Connection to system:

— phase to earth

— neutral to earth

— phase to phase

b) Type of equipment being protected:

— transformers (directly connected to a line or via cables).

— rotating machines (directly connected to a line or via transformers)

— reactors
— HF—reactors
— other equipment of substations
— gas insulated substations (GIS)
— capacitor banks

c) Maximum length of high voltage conductor between arrester and equipment to be protected (protection distance)

L-1.4 Characteristics of Arrester

— Continuous operating voltage
— Rated voltage
— Steep current impulse residual voltage
— Standard nominal discharge current and residual voltages
— Switching current impulses and residual voltages

For 10 kA and 20 kA arresters the respective long duration discharge class (*Clause* **6.6.4**)

— Pressure relief capability current (*Clause* **6.7**)
— Length and shape of creepage distance of arrester housing. Selected on the basis of service experience with surge arresters and/or other types of equipment in the actual area.
— Pollution Withstand Capability as per Annex I.

1.5 Additional Equipment and Fittings

— Metal enclosed arrester
— Type of mounting : pedestal, bracket, hanging (in what position) etc. and if insulating base is required for connection of surge counters. For bracket-mounted arrester whether bracket is to be earthed or not.
— Mounting orientation if other than vertical.
— Insulated base. Earth lead disconnector if required.
— Cross section of connection lead.

L-1.6 Any Sepecial Abnormal Conditions

For example : very frequent operation.

L-2 INFORMATION GIVEN WITH TENDER

— All points from clause

In addition :

— Reference current and voltage at ambient temperature. (**1.4**).
— Power frequency voltage versus time characteristics (Annex G)
— Lightning impulse residual voltage at 0·5, 1 and 2 times the nominal discharge current. If complete arrester acceptance test cannot be carried out at one of those currents the residual voltage shall in addition be specified for current in the range of 0·01 to 0·25 times the nominal discharge current (*see* **6.4**).
— Pressure relief device details
— Clearances. Mounting specifications.
— Possibilities of mounting. Drilling plans. Insulating base. Bracket.
— Type of arrester terminals and conductor size.
— Maximum permissible length of lead between arrester and surge counter and between surge counter and earth.
— Dimensions and weights.
— Cantilever strength.
— Medium of filling used in the arresters.
— Pollution withstand capability.
— Partial discharge levels.

(*Continued from second cover*)

Metal-oxide surge arresters were developed during the late 1960's and over the years, the technology has matured. These are now increasingly being used for overvoltage protection in power systems all over the world at almost all voltage levels. Use and, later, manufacture of metal-oxide arresteres in India started during the 1970's and the same trends are seen.

While these arresters have vastly superior protective characteristics compared to the gapped-type arresters used earlier, their design, testing and selection require detailed consideration or several aspects.

In view of these developments, this Indian Standard specification has been formulated to form the basis for design, testing, selection and application of Metal-oxide Surge Arresters Without Gaps for AC Systems. Although clarity has emerged on most issues, a few such as mechanical considerations and pollution performance are still under discussion. In order to give guidance in the interim period on these matters, the most appropriate procedures in the Indian utility practices and available specifications on them have been adopted in this standard. These will be reviewed and revised in future in the light of additional data and experience.

It is planned to bring out separate specifications on Surge Counters and Leakage Current Monitors which are often installed with metal-oxide arresters in EHV systems for diagnostic monitoring of their condition in service as well as an application guide for selection of appropriate arresters for use in various locations in power systems of supply undertakings and industries.

For the benefit of the users of this standard typical information required to be given with the Enquiries, Tenders and Orders are given in Annex L.

In the preparation of this standard considerable assistance has been derived from IEC 37 (Central Office) 38 'Surge Arresters Part 1 : Metal Oxide Surge Arresters Without gaps for A.C. systems' issued by the International Electrotechnical Commission (IEC).

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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